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A PILGRIMAGE TO THE HOME OF CONFUCIUS[1]

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THE fatherland of Confucius was a comparatively small kingdom called Lu, which occupied most of the southern half of the present province of Shantung. Tai Shan, the sacred mountain, stands near the northern border. Chufu, the birthplace of the sage, and where he was buried in 478 B.C., is about sixty miles south of the mountain, and nearly an equal distance southwest of the center of the ancient kingdom.

Shantung is called the Cradle of China. The Chinese really came from the west through the valley of the Yellow River, and, driving out or absorbing the original inhabitants, settled in the "region east of the mountains" (Shantung), whence they gradually extended their sway. The province has, therefore, been regarded as the home of the Chinese race. It gave to China its two greatest sages, Confucius and Mencius. Yao and Shun, the two heroes of China's Golden Age, worshiped on Tai Shan.

The Shantung men are stalwart and vigorous, with a reputation for turbulence and violence. In the province, the sturdy farmer thrives and looks upon his ancestral fields as sacred. Small holdings are the rule, and are cultivated with great care, for the population is dense. In the less fertile regions the struggle for a livelihood has become severe. Much of Shantung is mountainous, or unproductive, so that the great fertile plains are all the more crowded. In these congested districts a single bad year brings misery to multitudes of people, who migrate south on foot, or flock to the towns and cities and are supplied by the magistrates with a bowl of millet each, per day. In addition to famines caused by ordinary crop shortage must be added the havoc wrought by the chronic floods of the Yellow River and other streams.

The old walled town of Chufu is about six miles east of the Tientsin-Pukow railway, and prior to the revolution was governed by a direct descendant of Confucius (K'ung Foo-tsze) of the seventy-fifth generation. He was a duke under the Manchu empire, and was regarded as

[1] With photographs by the author.

SHANTUNG CARTS.

The native carts are very sturdy in order to withstand the vigorous treatment accorded them by the rough roads. The box rests directly upon the axle tree. The passengers are supposed to recline on the floor inside. The driver usually sits on one of the shafts. In the distance is a portion of the Spirit Road, bordered by cedars, which connects the Temple of Confucius with his grave.

the custodian of the tomb of the sage. Formerly he was not allowed to leave his place without special permission of the Emperor in Peking. Chufu is surrounded by a rather monotonous, fertile plain, punctured by numerous shallow wells for irrigation and dotted here and there with mud-walled villages, relieved by trees.

ENTRANCE TO THE INNER SACRED ENCLOSURE CONTAINING THE GRAVE OF CONFUCIUS.

This is the third gate. "We next entered (by the second gate) a cypress-shaded walk flanked by two pairs of huge stone dogs and ending at a third substantial gateway in front of which stood two stone figures, one a soldier, the other a sage, with a great urn between them."

We rattled and bounced to Chufu from the nearest station in stout, covered, two-wheeled carts, each drawn by a couple of stocky mules, hitched tandem. We were supposed to recline upon the floor, which, fastened directly to the axle-tree, magnified the inequalities of the lanes. The Chinese inverted sense of fitness applies to most rural roads. They are not publicly owned. In order to sacrifice as little of the precious land as possible, the farmers cause the road to meander the boundaries between two farms, so that one may travel very indirectly toward his goal. By constant packing and scraping of wheels, the way becomes worn below the fields, and during the rainy season serves as a

THE GRAVE OF CONFUCIUS.

Back of the altar is the mound upon which several small trees are growing. This grave with a few others are within a special enclosure. The very grass is sacred and endowed with powers of divination. The grave has been enlarged by handfuls of earth deposited by reverent pilgrims. Confucius was buried here in 479 B.C.

watercourse, to its further detriment. Then, being private property, the owner may draw upon it for supplies of soil to repair gullied gardens. On the whole, the road is a despised outcast, and although of necessity used by every one, it does not occur to the bucolic mind to accomplish any general repairs for such an impersonal quantity as the public. Dirt is far too valuable to be so wasted. As a consequence, although this particular road was exceptionally good, we had little opportunity for reflection.

Something like a mile from Chufu, a high plastered wall surrounds the most hallowed soil of China—a shaded park of many acres, where for nearly twenty-four centuries has rested the greatest of China's sons. We skirted the wall for a little distance, then entered a dreary hamlet, which, like a ragged beggar, displayed its poverty at the portals of the

THE GRAVE OF CONFUCIUS.

The mound is to the right of the monument which is in the center. The stone on the extreme right marks the grave of Confucius' son. On the left can be seen a portion of the chapel which stands on the site of a tiny lodge where Tze-Kung, a devoted disciple, watched for six years after the death of the Sage.

TEMPLE OF CONFUCIUS, CHUFU, SHANTUNG.

It consists of a long hall rising in one story to a great height. The pillars, of a yellowish-white stone, are wonderfully sculptured with dragons, and when tapped give forth a metallic ring. These, with the balustrades and gargoyles, at a distance remind one of huge pieces of carved ivory. Above, the eaves are intricately formed and variously tinted.

sacred precincts. Beyond the main entrance, as I remember, there is a pailow or honorary gateway, in front of an arched stone bridge over a watercourse, then dry. From this, a short avenue conducted us to another gate, at the right of which, surrounding a sort of rectangle, were several houses, used for guests and also as the dwellings of the guardians. We next entered a cypress-shaded walk flanked by two pairs of huge stone dogs and ending at a third substantial gate-way in front of which stood two stone figures, one a soldier, the other a sage, with a great urn between them. This gate gives entrance to an inner walled enclosure of a few acres, whose oaks, in bright autumn russet and yellow, relieved the somber hues of numerous venerable cypresses. We sauntered along a straight path for a short distance, and turning to the left presently found ourselves before the grave of Confucius, a mound upon which grow several small oaks. Its simplicity is very impressive. On a paved area in front of the hillock is a narrow stone table or altar supporting an upright inscribed slab of gray stone carved at the top, after the manner of memorial tablets in China. This is about all that art has supplied, unless we include a little chapel, hard by, which marks the site of a tiny lodge where Tze-Kung, a devoted disciple, watched for six years after the death of the master. Next to the grave of Confucius is that of his son, while scattered about the enclosure are others of minor interest. Three ornate chapels with inscribed tablets commemorate the pilgrimages of bygone emperors. The very grass that grows within this enclosure is sacred, endowed with powers of divination much beyond what we attribute to witch-hazel.

The mind falters to grasp the years which have gone since this grave was made. Surely the river of time has lingered in the pensive quiet of this ancient grove and then glided onward unnoted. Elsewhere, in that distant planet we so lately left, it has wrought with the

PILLARS OF THE TEMPLE OF CONFUCIUS.

These and the balustrades are of a sort of yellowish marble. Above, the beams are painted with conventional designs. The pillars of several associated temples are engraved with floral designs instead of being deeply carved.

dynamic violence of a mountain torrent. For, when the sage was laid to rest, Rome was an infant in arms, Socrates was not yet born, and Greece had not attained the Golden Age of Pericles. Yet, like those tufts of twigs which the spring freshets leave high and dry for autumn to wonder at, so in this sheltered bay the vernal flood of years has left a snag of cypress wood. It is just an old dry stump, held together by a band of iron. A tablet reverently pictures its form during life, and records its death, at the age of one thousand years, in the time of Charlemagne. Yet when this tree was a seedling, Confucius had been dead three hundred years—about the length of time since the Pilgrim Fathers landed in New England.

Outside this inner yard, but within the high wall, is a great host of tablets and mounds of seventy-five generations of the K'ung Foo-tsze

THE BIOGRAPHY OF CONFUCIUS ON STONE.

A fairly large hall at the rear of all the buildings contains a long barrier of polished stone, divided into rectangles whereon is pictured the life of Confucius with accompanying text. Although countless tracings have been made, the inscriptions are mostly still quite clear. These copies are made by placing moistened paper over the inscription, and then brushing over it an inky black paint, which leaves the characters white.

family, luxuriating, among scattered oaks and cypresses, in a wilderness of grass and weeds—a strange sight, this, in a country where everything inflammable is eagerly seized for fuel. The park is a veritable oasis in the rather dreary plain, and a haven of refuge for crows and other birds.

Chufu, which contains the finest Confucian temple in China, is really a big village. It is in the form of a rectangle about a mile in length by half a mile in breadth. One end of the enclosure is occupied

ONE OF THE NUMEROUS INSCRIBED MONUMENTS IN FRONT OF THE TEMPLE OF CONFUCIUS.

In the great court in front of the temple is a forest of stone slabs closely covered with inscriptions. Each monument was erected by a sovereign of the Empire, some of them dating back from 15 to 20 centuries. The great stones frequently rise from the backs of equally huge tortoises. Some of the monuments are protected by pavilions.

by the temple, which is connected with the burial ground by an avenue, overarched by stately cedars and adorned by two splendid marble pailows, one of three spans and one of five. This avenue is called the Shen Tao (the Spirit Road), meaning that the spirit of the holy man passes through these trees back and forth between tomb and temple. The temple is really a sort of vestibule to the tomb.

We drove about a mile through a choking dust to Chufu, but alongside the Shen Tao, because the avenue itself had become impassable through long neglect. The great temple and associated halls and courts are in a walled inclosure. The principal shrine resembles the Confucian temple at Peking but is vaster. Like all of its kind it consists of a long hall rising in one story to a great height. The pillars, of a yellowish white stone, are wonderfully sculptured with dragons, and when tapped give forth a metallic ring. These, with the balustrades and gargoyles, at a distance remind one of huge pieces of carved ivory. Above, the eaves are intricately formed and variously tinted as in most Chinese temples. Inside is a large figure of Confucius seated within a sort of recess elaborately decorated. Some of the principal disciples

AN INN YARD, CHUFU.

To the left is a group around an itinerant tinker. Note the cage in the tree. The Chinese are very fond of birds. The well is beneath the cage. The guest rooms, with no more furnishing than sleeping platforms, are at the rear.

are represented by statues of stone also, while numerous ancient bronze vases and elephants, and large yellow porcelain vases seem to be added in a spirit of decoration. Elsewhere, as a rule, the sage and his disciples are represented only by tablets inscribed with their names. The tablet in front of the statue of Confucius bears on it the inscription: "The seat of the spirit of the most holy ancient sage Confucius." Pendant from the vaulted roof are numerous gilded tablets setting forth the virtues of the sage. Tablets of seventy-two out of his three thousand disciples, who became conspicuous for wisdom and virtue, are ranged on either hand each in a separate shrine. In niches around the walls

A TYPICAL STREET IN CHUFU.

The houses are mostly of bricks plastered. Some are thatched and a few have tile roofs. One and all are most cheerless and uninviting. The streets are unpaved.

AN OX-CART IN CHUFU.

Away from the railroads, which are few, there is nothing in China which resembles rapid transit. Grain and other foodstuffs are transported to the rivers by ox-carts, or mule-carts, sometimes by wheelbarrows, and then freighted on slow-moving boats. In north China and Mongolia camels are much in vogue, and trains of pack-donkeys are a common sight.

are to be seen tablets of some of his eminent followers of later times. A cloud of incense fills the great chamber. Separated from this building by shaded courts are several other less pretentious temples. In these the two central pillars of the façade are sculptured in deep relief, while the laterals are engraved with flowers in graceful design, the peony being easily recognizable—all elaborately and beautifully executed. One of these temples is devoted to the memory of the father of Confucius, and another is sacred to the "Holy Mother," who trained and taught the Sage. The shrine to his wife (whom he is said to have divorced) is a simple tablet in a recess at the back of a special building. A fairly large hall at the rear of all the buildings contains a long

A PEDDLER AND HIS WHEELBARROW.

This man sells all sorts of small jars and earthen pots, some of which are supported on sticks in order to display them. The one-wheeled barrow is a very characteristic vehicle in China and unbelievable loads are carried on them.

barrier of polished stone, divided into rectangles whereon is pictured the life of Confucius with accompanying text. Facsimiles of this in book form are offered for sale by the priests. Although countless tracings have been made the inscriptions are mostly still quite clear. These copies are made by placing moistened paper over the inscription, rubbing it flat, and then brushing over it an inky black paint—probably manufactured from lamp-black. The paper sinks into the inscriptions and remains untouched, the characters thus appearing white against a black ground. In a fore court of the temple tracings were being made

from large tablets by men who worked with the abandon of a bill poster and left a goodly amount of the pigment on the stone.

In this great court in front of the temple is a forest of stone slabs, or columns, usually closely covered with inscriptions, and sometimes protected by a roof or pavilion. Each monument was erected by a sovereign of the empire, some of them dating back from fifteen to twenty centuries. The monolith is generally elaborately carved at the top and is borne on the back of a huge tortoise which shows a set of upper teeth with two projecting canines. An inscription by the Emperor Cheng Hua, 1465, refers to Confucius as "the Heart of Heaven without whom we should have been wrapped in one unbroken night."

Although he has a temple in every city, Confucius is not deified; he is never invoked in the character of a tutelar divinity. The homage paid him is purely commemorative. Confucius was not an originator; he was a reformer, selecting from the past and present whatever he deemed worthy of preservation. "I am not an author, but an editor," he said of himself. In this way, without assuming the rôle of a prophet, he gave to China a cult that reaches all classes, and a code of morals, which, however deficient in depth and power, still serves as a bond of social order. . . . Questioned as to a future life, he declined to dogmatize or speculate. "We know not life; how can we know death?" was his cautious answer. Yet he enjoined the worship of ancestors, a cult which has done more than any abstract teaching to cherish a belief in the survival of the soul.

A PRIMITIVE MILL, CHUFU.

The mill consists of a beveled roller which is pivoted to the center of a large flat circular stone, upon which the corn is spread. The donkey is blindfolded and is hitched to the roller. These mills are among the most characteristic features of villages in the north of China. Beyond the distant house may be seen the city wall.

A SMALL VILLAGE NEAR CHUFU, SHANTUNG.

This view was taken from the top of the mud wall surrounding the village and gives a good idea of a small Shantung town. The woman back of the house is splitting canes. These are first rolled with heavy stone rollers on hard ground, and are used for baskets, fences, etc.

The state religion[2] is not Confucianism, though founded on it. To the worship of Heaven it adds the worship of nature in its chief material forms, such as the earth, sun, moon, and stars, mountains and rivers. To the cultus of ancestors it not only adds that of heroes, but expands so as to take in many of the divinities of Taoism and Buddhism, thus forming a compound of the three religions. Logically the three are irreconcilable, the Taoist being materialism, the Buddhist idealism, and the Confucian essentially ethical. Yet the people, like the state, make of them a unity by swallowing portions of each. In ordinary their lives are regulated by Confucian forms, in sickness they call in Taoist priests to exorcise evil spirits, and at funerals they have Buddhist priests to say masses for the repose of the soul. Besides the women and the priesthood the two sects last named have very few professed adherents, though the whole nation is more or less tinged by them. The men (at least those who can read) almost without exception profess to be followers of Confucius.[3]

[2] That is, under the Empire; but it has really not changed.
[3] W. P. A. Martin, "A Cycle of Cathay," 1900, p. 288.

DEMONOLOGY AND BACTERIOLOGY IN MEDICINE

By JONATHAN WRIGHT, M.D.

PLEASANTVILLE, NEW YORK

IN the study of the theories of primitive medicine as set forth by the observers of modern uncivilized tribes and by the archeologists, the student is impressed by certain salient phenomena in the wild man's concept of disease etiology. He is also struck by the frequency with which first-hand observers, usually not medical men, adduce certain arguments by use of analogies which at first seem obvious, but which later to the professional man seem a little strained. The latter, I think, is apt finally to fall into the way of thinking of the phenomena from two points of view, one objective and the other subjective. Primitive demonology has been repeatedly associated with modern bacteriology by the ethnologist as a parallel etiological concept. He tends thus to bring into close apposition the first and the latest medical concepts of the causes of disease. It may not be uninteresting to review, in a very cursory manner, what we have learned of the universally accepted and long held theory of demonology as the cause of the ills of the flesh and of the spirit, from which man has suffered. Such theories were dominant until comparatively recent times—in fact during all but a few recent centuries of the many hundreds of years which have elapsed since we first catch a glimpse of the mentality of our ancestors. The traces of the idea are still so numerous and so apparent it is a work of supererogation to point them out in the current medical literature to discerning readers.

Before dwelling on demonology in the belief of primitive man as to disease we note the exceptions. We find primitive man thinking of disease as something which has gone wrong with his soul or his shadow or as due to the witchcraft of his fellows and finally to what we are pleased to call "rational" causes. We say these are the germs of "rational" medicine, but we must not lose sight of the fact that they were to him no more and no less rational than his other "reasons" for illness. They were undifferentiated. They were inextricably interwoven with his concepts of demons within and without him as the causes of disease and death. Over the whole was diffused a haze due not to deficient, but to unregulated mental processes—to mental processes which have less evolutionary past than our own. It was not because of lack of ability that he did not think clearly. Among them evidently there were men quite as capable of thinking clearly, but

doubtless they were as few as among us. It is said the vast majority of modern men only think they think and I suppose nothing more harsh can be said of the cerebral activity of primitive man. It is intimated that the cerebral functions of most of us now are mere imitations, reflex actions, mental contagion resulting in following the lead of some one who *can* think.[1] To think clearly is doubtless a rarity to-day, but we are justified in the belief that it was a much rarer phenomenon in the undisciplined mental activities of primitive man. This haziness of thought we must accept as undifferentiated, not as inferior mental activity. We can, thanks to our social and mental inheritance, differentiate demonology from other explanations of disease man made to himself in the infancy of the regulation of thought, but that differentiation is a modern not a prehistoric invention.

Inextricably bound up with the ills of the body among primitive men are the ills of the soul. Again it is all one and undifferentiated. His religion was real to him in the sense that it formed a part of the other realities of his environment. A very short reference to one or two aspects of this multiform pantheism will soon drift us into the demonology of disease. Thus his religious beliefs permeated his whole life on earth from the cradle to the grave and became a part of his very being, in a sense quite different from the spiritual inheritance he has left us. From the earliest times demonology was an essential ingredient of the oldest religious thought of which we have written records. A belief in every kind of demoniacal influence, which permeated not only the Babylonian and Assyrian people, whose heirs were the Jews, but the Hindus, was based on the supposed peopling of the air by spiritual beings—personifications or companions of storm and tempest. The very air itself had a spiritual meaning—expressed in etymology to-day. It is true some savages believe in beneficent powerful spirits or gods or even God, but for the most part they propitiate and concern themselves about the other kind, and pay little homage to those beings who wished them well, as indeed why should they? Their reasoning was much more consistent than ours. Why should a truly beneficent or a neutral God be propitiated? They needed all their slender stock of wealth and energy for the evil, aggressive kind. The idea of a beneficent god persecuting a poor human insect, busy with the mystery of evil, because he did not kneel to one superior to the demons that

[1] I do not think it necessary to pursue this train of thought further, familiar as it is to us in esoteric philosophy, but in self-defense I may add that I am conscious, if I did, of the necessity of entering into the interminable discussion as to how far, if at all, any thought is independent of "reflex action" and mental contagion and I suspect I should have to confess that essentially the "thought," of the follower is essentially the same as the thought of the leader. I am only here recalling certain conventional trends of modern thought, not asserting any justification for it in critical analysis.

dogged him did not readily enter their brains. We still are silent before the mystery of evil, but the heathen in his ignorance is not to be criticized for not being impressed with that kind of superiority or neutrality. He was very much more concerned, and rightly, with fending off devils of disease that lurked in trees and streams, praying to them as they still do in Shensi.[2]

There were those things in the wood and the water which had other functions, but the trees in Shensi are believed to be, as they are in other localities, "the dwelling places of spirits who possess the power of healing diseases and of bringing trouble to a happy termination," and when the sufferers who worship them recover, they furnish testimonials of their faith and gratitude by hanging red cloth on the boughs. Doubtless it is connected with the spirit worship of ancestors, which leads back to the necessity of diminishing their discontent. It is not always clear why certain trees are selected, nor why the trees sometimes cause misfortune and sometimes heal disease, but along the Han River

> The trees and rocks and the river itself are peopled by spirits, some of whom are good and some evil. The spirits are omnipresent and never sleep; they are all under the control of a mysterious being called the River Dragon.

There are few places left in the world where tree and water sprites linger to-day so undisturbed as they do in Shensi. In Australia they tell you:[3]

> Spirits were very plentiful before the arrival of the white man. A spring of fine water near Mount Kolor, called Lurtpii, was their favorite resort, and they were to be found there at all times by the doctor, who alone had the power to make them appear.

This needs no translation for us, familiar as we are with the harvest reaped still at "Springs" and "Spas" and "Bads" by modern wizards who people the evil tasting waters with healing powers.

From a recent remark of Dr. Mayer in regard to Papua[4] where the stone age lingers, we may see the reason why the primeval wizards more honestly entertained the belief in the magic of the waters.

> It is still a country of surprises, as when the petroleum fields, probably a thousand square miles in area, were discovered only about four years ago along the Vailala River, the natives having concealed their knowledge of the bubbling gas springs through fear of offending the evil spirits of the place.

It is quite evident here that the gas bubbles, inexplicable to the savage mind, were the "unknowable" element which deified the place and this may give us a clue to the gods and goddesses of springs at least. It is an excellent example of the readiness with which primitive

[2] Nichols, F. H., "Through Hidden Shensi." New York, 1902.

[3] Dawson, James, "Australian Aborigines." Melbourne, 1881.

[4] Mayer, A. G., "Papua, Where the Stone-Age Lingers," SCIENTIFIC MONTHLY, Vol. 1, Nov., 1915, p. 105.

man endows the "unknowable" with divinity so natural to man even to-day.

Though this belief in tree and water spirits is absent from the theology of many native tribes, as specifically, though qualifiedly denied by Williamson,[5] for New Guinea, it is a very striking phenomenon with many, and in the classic times of Greek and later European literature it was embodied in many graceful and poetic legends. A traveler in the Andean region of the Argentine[6] relates that one of his men having a headache he called in a female native doctress who promptly ascribed his illness to the evil spirit in a spring near which he had camped the night before. One of these evil spirits had also taken possession of a spring near a house which, though the best in the town, was shunned by the natives for fear of being killed by the maleficent being. In Africa, on the West Coast[7] several varieties of trees are believed to be inhabited by indwelling spirits, which are not exactly gods, but answer more to the hama-dryads of ancient Greece, or to the elves of medieval Europe. With these people as with all primitive man witchcraft is

> the chief cause of sickness and death. They can not, they think, attribute these evils to the gods, unless they occur in some way special to a god; as, for instance, when a man is struck by lightning, in which case the event would be attributed to Shango—or contracts smallpox, when the disease would be attributed to Shanpanna; for they are very careful to keep on good terms with the gods, by scrupulously observing their religious duties. They consequently attribute sickness and death, other than death resulting from injury and violence, to persons who have for bad purposes enlisted the services of evil spirits, that is to say, to wizards and witches.

This is but a glimpse at the manifold and innumerable instances obtainable from ethnographic literature, of the way all external nature is permeated by anthropomorphic concepts of a motive power, which still troubles our own synods. As primitive man interpreted phenomena external to his body so he interpreted queer phenomena internal to it.

> The belief prevailing through the lower culture that the diseases which vex mankind are brought by individual spirits is one which has produced striking examples of mythic development. Thus in Burma the Karen lives in terror of the mad "la," the epileptic "la" and the rest of the seven evil demons who go about seeking his life.[8]

In old times it was the custom in the Shan States, as in Burma, to bury alive a man or woman under the palace or the gates of a new

[5] Williamson, R. W., "The Mafulu; Mountain People of British New Guinea." London, 1912.

[6] Boman, E., "Antiquités de la region andine de la République Argentine et du desert d'Atacama." Publication of the Mission Scientifique. C. de Crequi Montfort et Senechal de la Grange, tome II., pp. 579–589. Paris, 1908.

[7] Ellis, A. B., "The Yoruba-Speaking Peoples of the Slave Coast of West Africa." London, 1894.

[8] Tylor, E. B., "Primitive Culture." 4th ed. London, 1903. 2 vols.

city, so that the spirits of the dead in guarding the place from human enemies should also keep evil spirits that bring sickness at a distance.[9] Evil spirits as the cause of disease is a theory of its origin and nature which occurs

> in various parts of the world, as for instance in Siberia among the Kalmucks, the Khirgiz, and Bashkirs; in many of the Indian tribes, as the Abors, Kocharis, Kols, etc.; in Ceylon; among the Karens; in the Andamans; in the Samoan, Harvey, and other Pacific Islands; in Madagascar; among the Caribs, etc. . . . So again in Guinea, the native doctors paint their patients different colors in honor of the spirit which is supposed to have caused the disease.[10]
>
> According to the Bukaua, disease is a personified thing existing outside of man. It is rather remarkable that though the Bukaua is acquainted with the internal organs of man, he places them in no relationship to disease.[11]

In India

> the people believe that in the blazing days of the Indian summer the Goddess Devi flies through the air and strikes any child which wears a red gown. The result is the first symptoms which less imaginative people call sunstroke.[12]

In Malaysia among the Mantra

> all diseases are believed to be caused either by spirits or by the spells of men. . . . The Swelling Demon haunts the abodes of men, whom it afflicts with pains in the stomach and the head.

In the ground there lives a demon

> who causes inflammation and swellings both in the hands and feet. . . . To enumerate the remainder of the demons would be merely to convert the name of every species of disease known to the Mantra into that of a demon or Hantu. If any new disease appeared, it would be ascribed to a demon bearing the same name.[13]

Im Thurn[14] very cautiously observes of some of the South American Indians.

> By some observers among these and other tribes in a parallel stage of civilization, it has been supposed that all diseases are also personified and regarded as possessed of spirits, just as are material bodies, animate and inanimate. But it seems to me that, at least in Guiana, this is not quite the case. . . . It seems to me that these diseases are not distinct beings, but rather forms, visible or invisible, assumed by the spirits of kenaimas, who, as has been explained elsewhere, are capable of throwing their spirits into any body they please. When, therefore, a disease-spirit situated in the bodily form of a stick or stone is removed from the flesh of an invalid, this bodily form is only one

9 Milne, Mrs. Leslie, "Shans at Home." London, 1910.

10 Avebery, Lord, "The Origin of Civilization and the Primitive Condition of Man." London, 1889.

11 Neuhauss, R., "Deutsch Neu-Guinea." Berlin, 1911. 3 vols.

12 Crooke, W., "The Popular Religion and Folk-Lore of Northern India." Westminster, Eng., 1896. 2 vols.

13 Skeat, W. W., and Blagden, C. O., "Pagan Races of the Malay Peninsula." London, 1906. 2 vols.

14 Im Thurn, Sir E. F., "Among the Indians of Guiana." London, 1883.

of the infinitely variable number which the kenaima is able to assume; and when a forest path is blocked against the advance of a disease, it is blocked against the bodily form of a malicious kenaima. In other words, diseases are not, I think, distinctly personified.

This seems rather the refinement of criticism of a scientist than entirely to exclude the personification of disease. Elsewhere observers have not made any qualification as to the conceptions they found. In the Fiji Islands[15]

one of the fiends had a monster front tooth which curved over his head, and bat's wings with claws and was usually regarded as a harbinger of pestilence. . . . Among their gods was a god of leprosy.

How firmly this idea is rooted in the minds of some primitive men is to be noticed in an observation made by Boas[16] on the Chinock Indians. One would suppose a gun shot or arrow wound needed no divinity to account for the ensuing trouble, but,

as soon as it is discovered that a person is shot his friends endeavor to take out the disease. The conjurer clasps his hands so that the thumb of the right hand is held by the fingers of the left. He catches the disease in his hands. It tries to escape, and when the thumb of the right hand comes out of the clasped hands the disease has escaped. While he holds the disease in his hands, five people take hold of him, two at his legs, two at his arms, and one at his back. They lift him; then a kettle is placed near the fire and filled with water. They try to bring the conjurer to the water, but the spirit of the disease resists. When he escapes, the men fall down, because the resisting spirit suddenly gives way. Sometimes they succeed in carrying the conjurer to the water. Then the disease-spirit is put into the water. When it gets cold it loses its power. Then they look at it. Sometimes they see that the spirit is made of claws of a wolf or of a bird; and someimes of the bone of a dead person, which is carved in the form of a man.

It is no less real an impersonation on the West Coast of Africa:[17]

When an Abiku has entered a child he takes for his own use, and for the use of his companions, the greater part of the food that the child eats, who in consequence begins to pine away and to become emaciated. If an Abiku who had entered a child were not bound to supply the wants of other Abikus who had not succeeded in obtaining human tenements, no great harm would ensue, since the sustenance taken could be made sufficient both for the child and his tenant. It is the incessant demands that are made by the hungry Abikus outside, and which the indwelling Abiku has to satisfy, that destroy the child, for the whole of his food is insufficient for their requirements. When a child is peevish and fretful it is believed that the outside Abikus are hurting him in order to make the indwelling Abiku give them more to eat; for everything done to the child is felt by his Abiku. The indwelling Abiku is thus, to a great ex-

15 Mayer, A. G., *Popular Science Monthly*, June, July, Sept., 1915, pp. 521, 31, 292.

16 Boas, Franz, "The Doctrine of Souls and of Disease among the Chinock Indians," *Journal of American Folk-Lore*, Vol. 6, Jan.–March, 1893.

17 Ellis, A. B., "The Yoruba-Speaking Peoples of the Slave Coast of West Africa." London, 1894.

tent, identified with the child himself, and it is possible that the whole superstition may be a corruption of the Gold Coast belief in the sisa. A mother who sees her child gradually wasting away without apparent cause, concludes that an Abiku has entered it, or, as the natives frequently express it, that she has given birth to an Abiku, and that it is being starved because the Abiku is stealing all its nourishment. To get rid of the indwelling Abiku, and its companions outside, the anxious mother offers a sacrifice of food; and while the Abikus are supposed to be devouring the spiritual part of the food, and to have their attention diverted, she attaches iron rings and small belts to the ankles of the child, and hangs iron chains round his neck. The jingling of the iron and the tinkling of the bells is supposed to keep the Abikus at a distance, hence the number of children that are to be seen with their feet weighed down with iron ornaments. Sometimes the child recovers its health, and it is then believed that this procedure has been effective, and that the Abikus have been driven away. If, however, no improvement takes place, or the child grows worse, the mother endeavors to drive out the Abiku by making small incisions in the body of the child, and putting therein green peppers or spices, believing that she will thereby cause pain to the Abiku and make him depart. The poor child screams with pain, but the mother hardens her heart in the belief that the Abiku is suffering equally.

There is always behind calamity some malignant power which selects the victim. The theory of disease among the American Indians of the Cherokee tribe Powell[18] sums up sententiously—"Animals, ghosts, witches." There are other causes in many tribes in almost every savage part of the world, but invariably the category includes these.

The Kafirs quite recognize that there are types of disease which are inherited and have not been caused by magic or by ancestral spirits.[19]

Of the etiology of West African diseases Miss Kingsley[20] says that some diseases are due to human agency:

The others arise from what is called witchcraft. You will often hear it said that the general idea among savage races is that death always arises from witchcraft; but I think, from what I have said regarding diseases arising from bush-souls' bad tempers, from contracting a *sisa*, from losing the shadow at high noon, and from, it may be, other causes I have not spoken of, that this generalization is for West Africa too sweeping. But undoubtedly sixty per cent. of the deaths are believed to arise from witchcraft. I would put the percentage higher, were it not for the terrible mortality from smallpox and the sleep disease down south in Loango and Kakongo, those diseases not being in any case that I have had personal acquaintance with imputed to witchcraft at all. Indeed I venture to think that any disease that takes an epidemic form is regarded as a scourge sent by some great outraged nature spirit, not a mere human dabbler in devils.

While essentially all disease, as we have seen, has its origin in the activities of ghost or spirit, or demon within the body devouring the patient's insides, they have not that concrete embodiment as a whole which is ascribed to the plainly contagious affections.

[18] Powell, J. W., Seventh Annual Report of the Bureau of Ethnology to the Secretary of the Smithsonian Institution, 1885–86. Washington, 1891.

[19] Kidd, D., "The Essential Kafir." London, 1904.

[20] Kingsley, M. H., "West African Studies." 2d ed. New York, 1901.

The Persian sees in bodily shape the apparition of Al, the scarlet fever: "She seems a blushing maid with locks of flame and cheeks all rosy red."[21] Amongst the spirits of disease, by the Mantra the smallpox demon is held in such dread that they have a repugnance even to mention his name.

Both the smallpox demon and the cholera demon, who is called Rak, are exorcised by means of a dance, during which certain magic formulæ are chanted by the magician.[22] From the same source we learn that

it will help us to an idea of the distinct personality which the disease demon has in the minds of the lower races, to notice the Orang Laut of this district placing thorns and brush in the paths leading to a part where smallpox had broken out, to keep the demons off; just as the Khonds of Orissa try with thorns and ditches, and stinking oil, poured on the ground, to barricade the paths to their hamlets against the goddess of smallpox, Jugah Penim. Among the Dyaks of Borneo, "to have been smitten by a spirit" is to be ill.[23]

In some parts of Africa a person dying of smallpox is not buried, "but the corpse is hung up to let the disease fly away with the wind, instead of keeping it about the place."[24] Thus we see disease devils without and within the body. I might go on to cite the instances of animals who have found their way into the wild man's insides, often causing mental troubles, or inanimate objects witched into him, as among the Australians or in South Africa, causing rheumatism and other troubles, but the list would be interminable. How these things work is probably not at all well figured out in the mind of primitive man. How a great demon with a curving tusk going up over his head would get inside of a little man it is hard to say. This is one of the things hid in the haze of primitive man's budding mentality.

Miss Kingsley in her humorous mimicry of West African English says:

In 1893 I came across another instance of the post-mortem practise. A woman had dropped down dead on a factory beach at Corisco Bay. The natives could not make it out at all. They were irritated about her conduct: "She no sick, she no complain, she no nothing, and then she go die one time." The post-mortem showed a burst aneurism. The native verdict was "She done witch herself," *i. e.*, she was witch-eaten by her own familiar.

In Guiana Kenaïmas,[25] in the form of worms, insects, or even inanimate objects, are supposed to enter the bodies of their enemies and there cause all headaches, toothaches, and other such bodily pains. In reference to the entrance into the body of worms and insects as the cause of disease, it is possible that the sight of dead bodies containing them may have given rise to the idea. Job (XIX. 26) refers to the worms

[21] Tylor, E. B., "Primitive Culture." 4th ed. London, 1903. 2 vols.

[22] Skeat, W. W., and Blagden, C. O., "Pagan Races of the Malay Peninsula." London, 1906. 2 vols.

[23] Tylor, E. B., "Primitive Culture." 4th ed. London, 1904. 2 vols.

[24] Werner, A., "The Natives of British Central Africa." London, 1906.

[25] Im Thurn, Sir E. F., "Among the Indians of Guiana." London, 1883.

which "after my skin destroy this body." Williamson[26] says of the people of New Guinea:

> A man with the toothache will say that "a spirit is eating my teeth." The people seem to have a knowledge of something inside the teeth, the nature of which I am not able to state definitely, but which apparently is, in fact, the nerve, and they recognize that it is in this "something" that the pain arises; but I could not ascertain the connection between this something and the spirit which is supposed to cause the trouble.

The way of thinking of the South Sea savage[27] is that in illness "the ghost is eating the patient," and the California Indians[28] believe the evil spirits "cause snakes and other reptiles to enter into their bodies and gnaw their vitals."

We can see how a thorn or a pebble in the cellular tissue causes inflammation, how the worms crawling from dead bodies may start the wild man's mind off on various theories of disease, but it is not always entirely clear to us, and their theories were doubtless not clear to primitive men themselves. They not infrequently sought to prove their validity. We have seen how they proved the woman with the heart aneurism had "done witched herself." In West Africa Miss Kingsley's attention was arrested by

> seeing several unpleasant-looking objects stuck on poles. Investigation showed they were the lungs, livers, or spleens of human beings; and local information stated that they were the powers of witches—witches that had been killed, and on examination found to have inside them these things, dangerous to the state and society at large. Hence it was the custom to stick these things up on poles as warnings to the general public not to harbor in their individual interiors things to use against their fellow creatures.

They needed but to open the bodies of the victims to find the same, and thus the connection between the two was manifest. The widow Douglas had always told Huckleberry Finn the world was round like a ball, but he never took any stock in "a lot of them superstitions of hers." So he used to go up on a hill and prove to himself it was flat because he "reckoned the best way to get a sure thing on a fact is to go and examine for yourself and not take anybody's says so." This is the true scientific spirit and in many modern scientific minds like Huck's and the investigators in West Africa, untrained in logic, it leads to like results. This lack of reasoning and analysis, very apparent to us in the records of observers of primitive man and not by any means unnoticeable in the "deductions," "conclusions" and "remarks" at the end of many a

[26] Williamson, R. W., "The Mafulu; Mountain People of British New Guinea." London, 1912.

[27] Williamson, R. W., "The Ways of the South Sea Savage." Philadelphia, 1914.

[28] Bancroft, H. H., "The Native Races of the Pacific States of North America." New York, 1875–76. 5 vols.

modern medical treatise, has in the course of ages perhaps been less conspicuous, but the way has always been set with pitfalls. After the rise of the cellular pathology we recognized that disease was dependent upon the destruction of cells. In West Africa the frequent localization of the devouring witch in the lungs is due, the Rev. Dr. Nassau[29] intimates, to the existence of the cavities of the third stage of consumption. He says in a footnote:

> Similarly I have known the fimbriated extremities of the fallopian tubes in a woman held up as proof of her having been a witch. The ciliary movements of fimbriæ were regarded as the efforts of her "familiar" at a process of eating. The decision was that she had been "eaten" to death by her own offended familiar.

This surprising note among other revelations demonstrates the value of early post-mortems. If you want to be sure of a thing, Huck Finn said, you want to go and see it.

Our cellular pathology seems now only a slight descent into the microscopic realm from the Zulu lesion, but at the time of its prevalence, we had become familiar with the action of chemicals and even of digestive juices on dead and living tissues. We knew of many chemical reactions in which the chief alteration of inert matter was one of oxidation, with the production of heat. Nothing was more natural than from this to arise an idea of inflammation in which the phlogiston theory was modified to express the destruction of tissue by a process of oxidation which accounted for the fever. Perhaps this is not wholly wrong as a conception of a part of the process of tissue destruction—not wholly wrong, but it was rapidly displaced by the advent of the living organisms of disease. We did not at first stop to inquire how they worked. We jumped at once from them to the lesion. Gradually bio-chemistry is coming to the fore and we are learning how the bacterial spirits of disease produce their evil effects, but with primitive man unacquainted with chemical action, when he got down to details, they were anthropomorphic—drawn from such experience as he had. The evil spirits bit and chewed and sucked the blood of the internal organs. How he thought the inert matter and the absent soul and taboos worked we do not know, but we have every reason to believe that, as a rule, he did not think at all. Even Lister felt it enough to demonstrate that germs present, disease occurs—absent, there is no disease. Lack of analysis in both cases is patent. We begin to know that disease germs present do not always mean disease present.

Demonology and modern medicine overlap one another throughout the whole historical period of 2,500 years, the thin edge of the latter reaching far back of Hippocrates and the tapering off of the former promising to reach far into the future beyond our day and generation.

[29] Nassau, R. H., "Fetichism in West Africa." New York, 1904.

One of the most learned of modern ethnologists curiously develops something of this train of thought—that interwoven with belief in the spirits of disease was an apperception of the truth which has swelled through the ages to the freshest of its manifestations in bacteriology. I quote from a recent article by Sir Harry Johnston,[30] who here seeks to illustrate the existence of that thin edge of the overlapping rationalism which lay alongside the large bulk of demonology—the orthodox faith of primitive man:

> Not only did the growing culture of the Neolithic and early Metal ages begin to perceive danger in the fly, in the locust, bug, tick, and mosquito, but an instinctive dread was felt of the invisible germ, the minute organisms which were not to be visually perceived by man till the seventeenth century of the Christian era and not to be in reality appreciated and understood till about fifteen years ago. This instinctive belief in the "germs" and the spread of germ-diseases was undoubtedly at the basis of the preposterous caste regulations developed by the Aryan invaders of a Negroid, Australoid India. They avoided the contact and even the proximity of the dark-skinned races over whom they had come to rule, because they associated such contact with the spread of disease. Though they assigned false reasons, they were right in the main—there is a good deal of common sense at the back of most religions—and it may only have been at first through the strictness of these precepts that the ancestors of the Brahman survived; though their descendants in modern India have resolutely fought the efforts to exterminate disease on the part of their recently arrived Nordic half-brothers, by refusing to credit the germ theories and to cooperate in modern measures of sanitation for the suppression of cholera, malarial fevers and plague.

At any rate, we may go far enough to assert that they were right to suppose that some external agent, demon or bacterium, introduced from without is the cause of most disease. Indeed, in pointing out the conception of a conflict of the evil spirits of disease with good spirits that defend the body within, we are perhaps within hailing distance of the time when Hippocrates defined disease as a conflict between opposing forces waged in the bodies of men and animals. It persists as the best definition of disease modern science can give, but the concept did not originate with Metchnikoff nor even with Hippocrates. For, of the people on the lower Niger, to whom neither Socratic nor Hippocratic wisdom seems to have penetrated, it is said that[31] "every medicine to be of any use must have within it a spiritual essence to defeat the operations of the aggressive invader. . . ." And they use certain, to us, senseless precautions

> in the firm belief that the spirit of the medicine will keep the spirit of the disease from attacking and infecting the wearers of the fetish. When, however, it fails to do this, the latter spirit has simply vanquished the former; the spirit of the disease has been too strong for the spirit of the doctor's medicine.

[30] Johnston, Sir Harry, "The Nineteenth Century and After." July, 1915, p. 151.

[31] Leonard, A. G., "The Lower Niger and its Tribes." London, 1906.

With anthropomorphic conceptions of the unknown, perfectly justifiable from their point of view, their actions, to us absurd, are entirely rational. Not only were various objects living and dead, as they are with us, made to serve as refuges for these disease devils, but to make the analogy closer we have seen Johnston trying to connect their demons up with our little devils, which at last we have managed to see. Innumerable forms and variations are to be noted in their medical practises, but they are all based on the idea that the cause of disease is some specific living object. We have identified it as a germ, but the germ of the idea existed many thousands of years before the discoveries of Pasteur and his predecessors. This similitude of conception has been dwelt on by others, especially by Miss Kingsley, who remarks of the devil sent in to drive away the disease devil, "a leucocytes versus pathogenic bacteria sort of influence, I suppose," by Johnston, just alluded to, and by another observer of the African mentality. Dowd[32] says:

> It is pretty evident to an unbiased mind that our microbe or bacteriological theory of disease is merely a thinly disguised imitation of the African spirit theory.

It is not only the ethnologist, but the archeologist whose thought is pervaded with this analogy between the primitive man's little demons of disease and modern man's devilish little disease germs. It is Jastrow,[33] the Assyriologist, who is struck by it. In old Babylon

> the evil spirits supposed to cause sickness and other ills were of various kinds, and each class appears to have had its special function. Some clearly represented the shades of the departed, who return to earth to plague the living; others are personifications of certain diseases. The existence of special demons for consumption (or wasting disease), fever, ague, and headache forms a curious parallel to specialization in the practise of modern medicine. There was even a "gynecological" demon, known as Labartu, whose special function it was to attack women in childbirth, and steal the offspring. . . . In short, like the modern "germs" of which they are the remote prototypes, they are universal and everywhere. They move preferably in groups of seven.

Elsewhere[34] he points out that in ancient Assyro-Babylonia

> a cure, therefore, involved driving the demon out of the body, either forcing him out or coaxing him out. Incantations as a means of bringing this about are therefore to be viewed as the antitoxins of primitive medicine, acting primarily on the demons, and merely as a resultant incident bringing about the cure of the patient.

[32] Dowd, J., "The Negro Races." New York, 1907–14. 2 vols.

[33] Jastrow, M., "Aspects of Religious Belief and Practise in Babylonia and Assyria." New York, 1911.

[34] Jastrow, M., *Proc. of the Royal Soc. of Medicine,* Vol. 7, No. 5, Hist. Section, 1914, pp. 109–176

Incantations, however, have not as much affiliation with modern bacterial therapy as another prehistoric performance. In Preuss's book on the medicine of the Talmud[35] he refers to the fact that Varro and Columella in the first century after Christ ascribed the diseases of Rome to little animals, which live in the swamps and are breathed in by men. These little animalcules he insists are no nearer parallels to the spirits referred to in the book of Tobit as *mazziqin* than are the microorganisms of the modern bacterial theory in spite of the fact that they closely resemble the concepts, if they are not identical with the Babylonian demons, that peopled the air of Mesopotamia and entered the bodies of men to their destruction. He admits that the Egypto-Assyrian prototype of the Jewish and Christian censers, smoking with resinous drugs which developed the antiseptic vapors of ethereal oils, forms some sort of a parallel with the now discarded weapons of the fumigators of our boards of health in their early bacterial days. His scorn of this sort of thing doubtless was expressed after the wane of this enthusiasm of early bacteriological orthodoxy. Nevertheless, even though no more than a coincidence, other things taken into consideration, it is rather remarkable that antiseptic ethereal oils were let loose in fumigation to exorcise the little demons of disease in old Judea some 3,000 years ago and let loose again some 30 years ago to exorcise the little red and blue devils we saw under our microscopic objectives. The efficacy of the fumigating performance, so far as the disease is concerned, doubtless was the same, but there is no occasion for scoffing at the performance at either date, but rather for reflection on the transitoriness of theory and the evanescence of facts. In disgust he says:

> Statt die heiligen Schriften zu verherrlichen, wie sie meinen, machen sie sie und sich lächerlich.

There is a good deal of the hiss about this, but it is indeed not Holy Writ that is made ridiculous alone. All but recent sanitary science comes in for its share.

As I remarked at the opening of this short review of an interesting passage in the history of primitive medicine, there is an objective and a subjective aspect of it. The phenomena as they presented themselves to primitive man's consciousness were practically the same in his time as in ours. "Here is a man well and like the rest of us yesterday. To-day he is languid and feverish and weak. Something ails him, something has got into him," to use a modern vulgar colloquialism which expresses it all, both in the ancient and the modern concept. "I have made acquaintance with a number of active two-legged things much like myself and I know other four-legged things less like myself and

[35] Preuss, J., "Biblisch-talmudische Medizin." Berlin, 1911.

some crawling things not at all like me. That's about all I know that harms a man." "Yes," says a skeptic, "but these we can see or feel or smell." "Whatever it is that has got into our fellow man doubtless is like some of the other things we know, only it can't be seen, nor felt nor smelt," says the ancient constructive scientist; "Must be something too small to see with the naked eye," says the modern theorist, who knows there are such things and how difficult it is to see them even through a double convex glass or even through a combination of them. Thus far then the prehistoric and the modern scientist follow the same trend of thought. They reason from a knowledge of things they know to things they do not know. Early man did not succeed in seeing his demon and he made mistakes about his attributes. Modern man finally saw the demon, but it is very evident that the early bacteriologists, who first saw him in connection with disease, also made mistakes as to his attributes, though they seem to have classified him a little differently. Reasoning from analogy is often man's only resource, but it is a fallible one and it is curious to see how it has helped him and how it has deceived him, both in his primitive and in his more sophisticated state. It is, however, all very logical. Given the same phenomena of nature and the same receptacle of the impressions they make—the same brain—we find the latter now making the same response to direct stimuli as it did at the dawn of the reasoning processes, differing only in the influence of an accumulated experience and in the inheritance of past achievements.

On the subjective side of this matter as I write I am reminded by a recent New England author of Puritan descent, somewhat given to forcing analogies, that

> what Augustine and Calvin saw, in the human affairs whence each alike inferred the systems of Heaven and Hell, was really what the modern evolutionists perceive in every aspect of Nature. Total depravity is only a theological name for that phase of life which in less imaginative times we name the struggle for existence; and likewise election is only a theological name for what our newer fashion calls the survival of the fittest. Old-world theology and modern science alike strive to explain facts which have been and shall be so long as humanity casts its shadow in the sunshine.

One hesitates whether to accept the view that the human mind runs easily only along certain grooves, or whether the impulses which set it in motion are really so identical in their tendencies and so accurate in their aims that ends are arrived at which if not identical are, it must be confessed, curiously analogous. On the whole our modern philosophy teaches us that the impulses may be marked, but more or less indeterminate and aimless. The mental momentum they set up glides into

grooves or paths which previously expended energies have ploughed and blazed through the intricacies of past cerebral activities. It is in this way we may account for the complacency with which the fit who have survived contemplate themselves as the elect and in the analysis demonolatry can claim what it really had in mind all the time was bacteriology.

THE REAL IN SCIENCE

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WHEN one looks over the world of natural phenomena and begins to study it in all its complexity, his usual motive is that of organizing it in some way, so that he may lose the feeling of bewilderment and the sense of being overwhelmed by the multitudinous sea, and the scornful mountains, may in some way feel that he is master of the serene clouds and the flash of lightning. He feels within himself that he is superior to these exterior things in many ways, and that if he can understand them and their ways of behaving he can control them. He is also dominated by a feeling for beauty, and the disorder he finds in his impressions of the world shocks this esthetic sense, so that he undertakes to examine the world closely to see if perchance there be not some hidden beauty in it after all. In the pursuit of these aims he describes and catalogues facts, orders them by relations that his mind finds, deduces statements that comprise many facts in small compass, generalizes these into laws, and the laws into systems of science. He endeavors to reduce the number of variables in terms of which he desires to express himself to the fewest he can. He thus comes to feel in the end that when he has succeeded in stating an unlimited number of facts in a few laws containing a few terms, and particularly when by these he can make predictions that are closely fulfilled, he has discovered the reality of nature. He thinks he has analyzed phenomena into their constituent elements, and that these elements are permanent and unchanging in their real nature, and he considers that therefore they may be correctly called realities. We may, therefore, as philosophers ask the scientist to justify his claim that he has found reality. Many scientists of late have considered the challenge. Instances are Poincaré and Enriques, who have treated the problem in masterly fashion. It is indeed the scientist himself and not the philosopher who can properly consider the problem, for science must be allowed to speak from its own standpoint, and value its results by its own standard. We may, however, all of us, pass judgment on the content science puts into the word real, and upon the precision of its statements as to what it desires to prove regarding the real.

We need too to take into account the very closely allied field of mathematics, for we must not confuse mathematics with science. They differ radically in content, method, foundations, objects, and validity

in experience. The more fundamental would seem to be mathematics, for we can scarcely eliminate it from any kind of thinking. In science particularly the dependence is great. We find, for instance, that the planets describe twisted curves through the centuries; lines of force stream like gossamer threads from electron to electron; the quivering ribbons of the aurora illuminate the pages of electrodynamics; particles of air leave streamlines with intricate turns and interwoven loops, with vortices whirling in the turbulent current; the molecule zigzags its dizzy path through the colloidal solution; wave-fronts that bend and warp fly through space with every snap of the wireless; quanta of energy, electrons, magnetons, as well as gravitational particles, if there be such, make space granular with singular points; the facets of every crystal flash with groups, electric and magnetic fields move like expanding clouds, with congruences of lines darting out like lightning flashes; the trihedral of polarized light spins like a firework; the spectrum hues are close to the roots of an infinite equation; the moving system finds a minimum variation; the mended rubber tube is full of integro-differential equations; the laws of statistics blush in the petals of every daisy; and nature in her wildest vagaries preserves the decorum of the laws of probabilities. One may study mathematics with little study of science, but one can not go far in science without the constant study of mathematics. Mathematics conditions the scientist with inflexible rules, which he must not transgress, and, at the same time, it gives him freedom from postulates that he himself at first considers binding, together with methods that are independent of the visualizing power or other concrete modes of thinking. It thus becomes evident that the answer to many an inquiry of the philosopher in the field of science may be discovered by asking the same question in the field of mathematics. The wistful soul of man has often turned to both, indeed, asking for real gems and a draught of real inspiration, after it has been deceived by the magician's fool's gold and glittering mica which it took for real wealth, or has panted long and far after the philosopher's mirage with cool waves and shady palms that only tantalized its thirst.

The real in knowledge—which does not vanish as the dew in the morning sun, or the mist in a frosty night; the real of knowledge which does not beckon like the will-o'-the-wisp to swamps and mires; the real of knowledge which does not in the eating turn to ashes and bitterness —the real of knowledge, which is as fixed as the constellations that stud the nightly sky; the real of knowledge, which is as solid as the ragged peak, defying storm, wind, lightning, and seasons; the real of knowledge which illumines the path with a flood of white light—where is it to be found? Is it only a vain hope? We turn to mathematics and can answer confidently, no. For through the turmoil and vicissitudes of

eight millenniums, through the whole enormous stretch of human history—we find arithmetic, the guide of the astrologer predicting the fortunes of the royal infant, and the companion counting the pennies of the flower girl in the streets of Babylon; noting the tale of conquered land under Rome, and the vanishing ranks of the crusaders; building the towers of modern Babel, and numbering the loaves of bread the poor shall eat to-morrow. Here is a kind of reality, at least. Again for three millenniums, we see geometry settling the property-rights of the Nilean owner, determining the blocks of the pyramids, constructing the Eiffel tower and the Quebec bridge. Here-in is surely the real. For how can that which is not real persist for thousands of years? During the last century and a half, mathematics has determined the swing of the stars in their courses, it has built telephones and telegraphs, saved the victims with wireless, and is present in every sphere of human life of to-day. There must be reality in its world, for how else could these facts be?

It is a hoary question of the race. Perhaps not arising in ancient Asia, for there the search was not for reality, but for a mystical Essence older than life and nature; but in Europe the problem was discussed many centuries ago.

There was a brilliant genius, who watched the stately march of the stars from the mountain tops of Samos, or drew diagrams on the wave-washed sands of the Icarian beach, or laid out magic squares, or charmed his select group of initiates with his lyre and the beautiful relations he had found to exist between tones and numbers. In the cube he found a symmetry of form, and in its 6 faces, 8 vertices, and 12 edges, numbers that gave the fundamental tone, the quarter, and the octave, harmony in form, in number and in music combined. How far he penetrated similar symmetries in the world about him it is hard to say, but certain it is that he saw the universal presence of mathematics, and the intuition flashed through his mind into the world that mathematics could account for the whole universe. Mountains and sea, the soul of man, and the justice in society, could be explained in this way. Triangles, squares, pentagons, spheres, cubes and other figures were certainly incarnations of number, and so were tones of the lyre, why not all the phenomena of nature? The heavens must rotate in perfect circles, and there must be a music of the spheres so subtle in its numerical structure that only the most profound could hear it. The earth must be a sphere, for was not the sphere perfect in all its parts? If he had sensed the modern group as it is present in crystals dug from the mountain cavern, he would have been even more firmly convinced that number is at the heart of every structure. But he did have the vision of mathematical concept matching natural object, mathematical

structure matching the intricacy of natural phenomena, yet all with certainty, elegance, proportion and harmony. He saw mathematics building a tremendous symphony out of the orchestral music of nature. Across twenty-five centuries we see Pythagoras's majestic figure and appreciate his far-sweeping vision.

Half a century later Heracleitos mused by his fire on the bank of an Ephesian brook. The fuel disappeared as the flames danced and the smoke drifted away. He watched the water hurry over the rocks in a tumble of white foam, sweep past and vanish down the slope. Mists rose from the Ægean Sea and became drifting clouds; they broke and descended in rain which disappeared into the ground. He too had the penetrating vision of the seer as he watched the glow of the coals, and with much irony on the folly of the half-informed, the reveler, and the fickle-minded, he drew his vision in a few immortal strokes:

> Fire lives by the death of earth, and air by the death of fire; water lives by the death of air, and earth by the death of water. This order, which is the same in all things, no one of the gods or man has made, but it was ever, is now, and ever shall be an everlasting fire, fixed measures of it kindling and fixed measures of it going out.
>
> You can not step twice into the same stream, for ever fresh waters flow in upon you.
>
> The quick and the dead, the waking and the sleeping, the young and the old, are the same; for the former are changed into the latter and the latter into the former.

Is this only vague Hellenic metaphysics? Salt disappears in water and we have neither salt nor water; the molecule breaks up into atoms, the atom into electrons and nucleus, which are all in incessant motion, and occasionally explode so that new atoms are formed. The nucleus shrinks and expands and may itself be a complex system. Energy flows out into space and is dissipated, whither who knows? Nor whether it may not be regathered into blazing suns! The Brownian flashes, the pulsating cell, the evanescent process of mind, all prove that the universe is incessant change, and that it is extremely unlikely that any one of its configurations is ever repeated. The song vanishes with the singing, the landscape with the seeing, the dream with the dreaming.

> Onward and on, the eternal Pan,
> Who layeth the world's incessant plan,
> Halteth never in one shape,
> But forever doth escape,
> Like wave or flame, into new forms,
> Of gem, and air, of plants and worms.

Did not Heracleitos have a vision of the evolving universe, wherein all is in motion and motion is in all, whether particle of ether or propagation of an insubstantial state, or the intermingling fields of electric and magnetic action, or the creative evolution of electron, matter, and life?

Yet another half century and we stand with Parmenides on the shores of the blue Mediterranean, the same day after day and night after night despite dancing waves and casual sail; admiring the golden sunset that came every evening, the same sun in spite of storm and wind; the stars in rigid constellations traversed the dark blue sky, preserving their paths despite the few wanderers; the Italian mountains in the distance always the same despite the shifting lavender, amethyst and purple on their slopes. Austere and dignified one must be who sees things like these, and what he thought he put into a poem:

> The world is, and it is impossible for anything not to be. For one can not know what is not—that is impossible—nor utter it, for it is the same thing that can be thought and that can be. It needs must be that what can be thought and spoken of is; for it is possible for it to be, and it is not possible for what is nothing to be. What is, is uncreated and indestructible, alone, complete, immovable, and without end. Nor was it ever, nor *will it be;* for now *it is,* all at once, a continuous one. How can what *is* be going to be in the future? or how could it come into being? If it come into being it is not; nor is it going to be in the future. Thus is becoming extinguished and passing away not to be heard of. Moreover it is immovable in the bonds of mighty chains, without beginning and without end; since coming into being and passing away have been driven afar, and true belief has cast them away. And there is not and never shall be any time other than that which is present. Wherefore all these things are but the names which mortals have given, believing them to be true—coming into being and passing away, being and not being, change of place and alteration of bright color.

But this too is modern science, for is not energy always energy, helium always helium, electrons always electrons, momentum always momentum, ether always ether? From acorns we always have oaks, and from thorns never grapes nor figs from thistles. The wave runs over the field of bending grain, but the motion is illusion, for the grain is always there; glacier and sea and cloud seem diverse, but are in reality only forms of the same water; the moving picture is a clever trick, which shows that all motion may be mere illusion; actual diversity of substance no longer exists in chemistry, the only diversity being one of combination, just as groups of men collect, and separate to form new groups. We can very well agree with the vision of Parmenides as he looked across the sea from his lofty summit, for the aim of modern science is to discover if it can the ultimate realities in terms of which all the forms of nature may be stated. For this reason it invented an ether, in which indestructible, uncreatable vortices constituted matter, stresses constituted electricity, while all the phenomena of electromagnetism were due merely to ether flow. It is for this reason that science seeks to reduce all the phenomena of life to the nicely balanced play of forces that are already in the system and to account for behavior in the same terms. This is the monistic dynamical view of the universe. We need not pause to trace its forms throughout the twenty-

four centuries since Parmenides, nor the forms of the views of Heracleitos or Pythagoras, for they have appeared many times as new philosophies, more acutely stated but not more far-reaching.

Daring thinkers they were, who had no degrees, no elaborate equipment, no research programs, no reference libraries! They faced the sphinx and from her mysterious lips heard answers which were contradictory and yet all correct. Who denies to-day that the world has a mathematical structure, from the electrons in their orbits and the quanta flung off from the radiating vacuum? Who denies the universal validity of the laws of conservation of energy, of momentum, or varying action? Who does not see the instantaneous evanescence of all the phenomena of experience as the mighty pendulum of eternity ticks off the seconds of the universe? Whence? Whither? What? Is the world but the projection of a mighty lantern on the screen of the senses? Are we tricked into imagining there is something real and permanent in the universe? Is the mathematical structure after all the only permanent part of the universe, and the other seeming realities merely aboriginal and naïve delusions, like the ghosts, goblins, elves and phantasms of the past? When we read modern works on electrodynamics, we seem indeed very close to this view, for the geometry of a non-Euclidean four-dimensional space seems amply able to state every known phenomenon of physics and chemistry. Or does indeed the mathematician dream, and in his dream see a fairyland of frost which is too beautiful and too fragile to exist in the sunlight of prosaic every-day life? Many things once thought real have vanished. The ether was so real that its density was about that of air on the summit of a mountain two hundred miles high, its rigidity about a billion times that of steel, yet to-day what is the ether? The mass of a body was once supposed to persist through the most fiery tests, yet to-day it varies with every change in velocity, and may be merely a number which is zero when there is no velocity. Space at least was supposed to be exempt from the vicissitudes of public opinion, and the intense cold and emptiness of interstellar space has chilled many an emotional mind. Yet to-day we have our choice of three incompatible spaces for the universe to exist in, with absolutely no way of ever deciding in which we really live. Time was supposed to be almost the last foundation of the world, even under the series of caryatides that supported the universe, but time is for science to-day a local phenomenon, so that we do not know what the same time in Europe and America can mean, and events may happen which are neither simultaneous nor yet one before the other. The dimensions of space seem a fundamental reality, yet we do not know whether we live in four dimensions or more, or simply three. Inspect the list of terms from modern science closely: ether, electron,

energy, mass, space, time, dimensionality, and we might add many more. Do they represent realities or are they merely fancies of our too easily illusioned minds? Where is the criterion we can apply with some assurance of certainty?

Is it in the senses through which all observations are made? Who then has seen the ether, or space, or a wireless wave? Who has heard energy or put entropy into a vial to be smelled or tasted? What sense feels the X-ray, or what finger can wind up the magnetic line of force? Who ever moved a Faraday tube with its ends fixed—that reality of which Thomson builds all electrodynamics? Who can detect gravity by his senses as it swings the stars along their ponderous curves? Even if recording instruments of every type, cameras, chronographs, or automatic apparatus of every description, had for thousands of years kept as faithful an account as the recording angel, nowhere should we find in these records energy, space, waves, entropy, temperature, fields of force, life or mind. None of these is to be grasped by the senses. Even number—that is not given by the senses either. I sit by the table and watch the flashing scales of the goldfish in its bowl. I see one fish through the side of the bowl, another through the top of the water. My finger reports one fish, my eye two. Feature to feature, shining scale to scale, motion to motion, the two fish are exactly alike. Does my eye report reality if there be one fish, or my finger if there be two? If one, which one is the real one, which the illusion? Even a camera would show two fish, yet a balance would show but one. And the whole of human experience reveals the same doubtful character of the testimony given by the senses. Unless we were to arbitrarily endow ourselves with an intuitive power of seeing with an internal eye realities given by the senses, we must admit that if only what the senses report is to be accepted as fact then we are poor indeed in realities. Heracleitos must have been right, for the world of the senses is ever shifting, ever new, always a swiftly flying present, and full of contradictions.

Is reality then to be found only in our inferences and deductions from the phenomena of experience? From the observations of his predecessors Ptolemy inferred a structure of the universe which is complete, accurate, and can never be contradicted by nature even if nature should turn out to be full of discontinuities. For his system was built on Fourier series, though he was unaware of the fact, and even discontinuities do not bother Fourier series. Yet we accept as the reality in the structure of the universe the Copernican system. Can then inference give us unreality as reality? Maxwell proved that electricity was an ether stress and discovered wireless waves merely by inference. Yet there is no ether and a wireless wave is a wave with nothing to wave. Indeed it makes no difference whether we suppose there is an ether or

that there is not an ether. Where then is reality in inference? Is the inferred rotation of the earth a reality or merely a convenient fiction? When we see the Brownian fireflies in the ultramicroscope, are the flashes reflected from the surface of a molecule, or from the modern complicated system called an atom. The latter statement is much like saying the solar system reflects light. Is color real, or is the reality only a number attached to a periodic phenomenon which has lost even the tenuous phantasm called an ether as its support? Is a symphony only imagination, while the reality is a series of complicated pulses propagated through the air? Is a cube real? For thousands of years men have studied the cube and always reported the same facts and theorems about it. Inferences may not give us reality any more than sense-perceptions. We find the same contradictions everywhere and not merely confined to physics or chemistry, biology or psychology. For long ago the Sphinx crouched no longer in stone:

> She melted into purple cloud,
> She silvered in the moon;
> She spired into a yellow flame;
> She flowered in blossoms red;
> She flowed into a foaming wave;
> She stood Monadnoc's head.
>
> Thoro a thousand voices
> Spoke the universal dame:
> "Who telleth one of my meanings,
> Is master of all I am."

Perhaps here is the way out of our difficulties. If we can unriddle the problem of reality in one instance we may hope to do so in others. Therefore we turn to the universe of the mathematician, for here indeed the problem has been solved, and what reality is, what fiction is, can be ascertained.

II

Mathematics is a vast world of objects and their transformations with both static and dynamic features, intricate and tangled, yet systematic and ordered to a degree far greater than any other known world at present. It is a world created by the mind of man, partly in order to enable him to handle the numerous phenomena he studies, but mostly for the elegant beauty of the objects. The mathematician is an artist who works in a more subtle material than paint or stone, or even tone and words. In recent years he has busied himself with a consideration of just what kind of world he dealt with, and he finds he does not discuss the natural world, though he may receive suggestions from it, but that he creates a world and that the objects of this world grow more numerous day by day, more elaborate, more interconnected, and

yet as time passes this world is permanent and becomes a heritage of the race. The mathematician has concluded that man has always exercised this creative function of his intelligence, indeed perhaps that is the chief function of intelligence. He is convinced that the unknown is merely the uncreated, that uncomprehended complexity is merely chaos and not complexity at all. We can not stop to consider this conclusion of a large number of the masters in this branch of human knowledge, but we may notice just a few of the lines along which this creative evolution has proceeded.

Before the pyramids reared their vertices toward the Egyptian sky, before the valley of the Euphrates was cultivated for its grain, long, long before the first record of history there were men who fought the wild beast and took from him his skin; who fished the lakes and carried home their catch; men who met each other and compared the objects they had gathered. Desire for the other man's booty arose, and when they did not fight for the possession of the treasures, they bartered for them. A skin for a carcass, a small skin for a fish, a handful of fish for glittering stones or perhaps for curiously marked shells; at first a direct handing over of object for object, but later a tally of the objects, a conception of the fact that the parts of the body could represent the collection to be bartered—such was the beginning of the haughty aristocrat of mathematics, the theory of numbers. The Zuñi tallies with his fingers successively and says: the beginning, taken with the first, the middle of the list, all but one, the lot, one with the lot, another with one and the lot; the Bugalai says, little finger on the left, second finger, middle finger, index, thumb, wrist, elbow, shoulder, left breast, right breast; the Australian knows but the single thing and the couple; the Polynesian counts by pairs, by quadruples, and by tens, hundreds, and thousands, for he laid out small objects by pairs, one in each hand, and breadfruit he ties in pona of four each, so that takau means ten, twenty, and even forty; the Maya counted by scores and scores of scores. In this simple manner was suggested to the mind first the correspondence of the tally, then the image of the tally, and finally one brilliant day there flashed into existence the concept which dispensed with the tally and the image. At first the primitive bookkeeper kept his accounts by tallies of some sort, but in the course of time as transactions were more complicated, he was forced to invent a two, a four, a five, a ten, a score, a hundred, a four hundred, even a million, which did not consist of the tallies nor of the parts of the body that were used to tally, but of real abstract numbers. For these he invented arbitrary signs, which no doubt were crude imitations of the objects he had used for tallies. When we reach civilization's story we find the Chaldean astrologer counting by sixties, and writing his numbers by the principle

of position of the symbols, so that he has even sexagesimal fractions, a very elaborate system indeed. Ultimately man was compelled to study this world of number that he had thus created, not as a sort of distillation of many trades or barters, nor as a shadowy composite photograph of the various pairs, quadruples, tens of millions, that he had seen or handled, but as a sharp and definite concept of an object which could not be perceptually visible, but which nevertheless existed in the imagination as a real object. The mathematical imagination, in other words, had begun to create the series of objects which through long eras has become a tremendous world almost commensurate with the world of phenomena. We may easily imagine the primitive bookkeeper keeping tallies on a stick, just as many of the ignorant of our own time do, with big notches for the tens, and very large ones for the hundreds. We may imagine their admiration for the genius who first invented symbols for the tallies and kept the count in his head, taking the objects to be bartered by fives or even tens instead of by ones. We may speculate about the prehistoric period during which these symbols grew in different places into systems of notation, in Chaldean cities becoming the very intricate sexagesimal scale which was useful to the wealthy Babylonian as he counted his millions, and to the astrologer who scanned the jeweled sky for mystic information. The invention of such a system of objects with their multiplication table, addition table, notation of a very effective type, the ability to calculate by means of this invention, and thus to dispense with the handling of large groups of objects, was surely a brilliant inflorescence of the human mind. It eventually dawned upon the mind that in these numbers alone there was a world very well worth the study, and while Cyrus was seizing the treasures of Crœsus, while the Cumean sibyl was burning her prophecies by threes in front of Tarquin, Pythagoras was instructing his initiates in the mysteries of even and odd, and even-odd numbers, perfect numbers, the harmonic mean, squares and rectangular numbers, squares whose sum by twos is a square, and other properties of these purely mathematical objects. They hoped indeed to explain the whole universe by means of these properties alone, just as many another philosopher since has hoped to resolve the universe by means of other mathematical creations.

An unlucky day for them, however, and a lucky day for us came when it was discovered that the diagonal of a square could not be represented by an integer, no matter what number was taken for the side. Here was a downright failure to explain even mathematical objects by numbers, that is the natural numbers, and all hope of extending them to the universe vanished. It was a lucky day, however, because it suggested to the mind that the list of mathematical objects

be enlarged by the creation of the irrational numbers. These include not only the radicals, like $\sqrt{2}$, $\sqrt{3}$, $\sqrt[3]{2}$, etc., but infinitely many more, such as π, e. Up to the present time no need has been felt to create a further addition to the list. Should the time come, however, as there are some indications that such a time is almost at hand, when it will be necessary, in order to deal with phenomena, to have a set of numbers of higher dispersion, let us say, they will be easy to create and will be readily studied. The modern theory of pointsets and of ensembles in general will take care of this. With the creation of the irrational disappeared counting on an abacus, or tallies of any kind. Concrete objects are useless in handling these numbers, and the mathematician must use his inner eye.

For more than two millenniums the world of number had no evolution. Kingdoms rose and fell, wealth was gathered and vanished to the corners of the earth. Learning of one kind or another made some advance, but the mind was content with its numerical system as it was. Then while Thomas à Becket was quarreling with Henry II., while the crusaders fought about Jerusalem, on the banks of a lotus pond in India Bhaskara watched the swaying lilystalks, and the golden bees that settled in the flowers, and wrote a treatise on "The Beautiful Science, *Lilavati.*" Perhaps he was not much more than a compiler, but at any rate we find in his book a new and startling kind of number: numbers that were at first called less than nothing, negative numbers, numbers of which he says the people do not approve. These numbers arose just as did the natural numbers, in the attempt of the human mind to manage the world of its experience. In trying to solve quadratic equations the mind had found it necessary to invent a new kind of number, for sometimes the equation could not be solved without using what we now call negative numbers. Nowhere in all the barters and the mercantile transactions of the past had there been anywhere found a negative number, any more than there is an irrational number to be found in nature. These had arisen as necessary to satisfy the symmetry and harmony of the mind's own world of number, and for purely conceptual reasons. True, in the course of time it was found that the bookkeeper might use these numbers in his credit accounts, if he so chose, but for many centuries they were considered as purely fictitious and of doubtful utility.

The Americas were discovered, and while DeSoto was exploring the Mexican deserts another unscrupulous adventurer was exploring the deserts of algebra, finding and passing by as unprofitable one of the strangest flowers of the field of thought. The square root of minus one, a more daring conception than had yet burst into bloom in all the history of human knowledge, after centuries of slow evolution of the flora

of arithmetic, sent up a solitary stalk and spread its petals to the brilliant sun of the renaissance of thought. Shunned at first as if it were the work of an Aztec sorcerer, for three centuries it slowly spread, until in the modern theory of functions of a complex variable it began to be cultivated for its far-reaching uses. A creation directly from the mind of the race, never discovered in trade, nor in any application, looked upon as an impossibility for centuries, still called imaginary, it has become indispensable even to the practical man. For listen to the wireless call for immediate help, and know that therein is the essence distilled from this once unknown, uncreated flower. The years passed to the number of more than two hundred and fifty, before even a geometrical application was found for this imaginary number and its kind. Certainly we have here at last an indubitable creation of the mind of the mathematician. And, almost 300 years after its appearance, the brilliant Hamilton announced a new variety of number whose inflorescence is clustered in tetrads of imaginaries, and whose beautiful symmetries are the delight of all privileged to perceive them. Since his time species of number have appeared bestarred with imaginaries of very bewildering types, hypernumbers of almost infinite variety, and the mathematician is aware fully at last that he can at will, like Prospero, summon these magic flowers from the chaos of the uncreated, but unlike Prospero's cloud-capped towers they do not vanish with a wave of the wand, rather they spread luxuriantly and bloom superbly, and from them we extract elixirs and perfumes.

We turn back the record again to the age of the Seven Wise Men of Greece, to the beginning of the geometry that was destined to be one of the glories of early Hellenic thought. Whatever it may have been under the great thinkers of Chaldea and of Egypt, it is here that we first find it spreading wide its theorems. Indeed so marvelous was the development of the geometry of Euclid and his successors, that for two thousand years it seemed as if here indeed mathematics had met reality and conquered it. The irresistible power of logic seemed to open all the secrets of space, and it was as rank heresy to question the *a priori* character of geometry as that of theology. Galileo horrified the authorities with his assertion that the earth moved, and a century later a timid Roman priest undertook to show the heresy in supposing that every line had several parallels through a single point. He failed mathematically, his name is almost forgotten, but unwittingly he too had seen the first single flower of another new world. Many decades later Lobachevsky, bolder even than the great Gauss, deliberately set forth in this new world and found that the journey was pleasant and beset with no precipices. Riemann a little later created a third world of geometry, which has in it no parallel lines, no similar figures, nor any solitary wastes of

infinite space. And these three mutually exclusive worlds are now at hand, incompatible with each other, each as infinitely logical as the others, each as fully capable of being the reality of the space we face every day as the others. Riches indeed we now possess, far beyond the dream of Parmenides, for even though the stately architecture of each of these worlds is far more abiding and permanent than the Parthenon itself, yet the three can not exist together, and experience is powerless to tell us either which one is the geometry of the world we live in, or to explain then whence arose the other two. To state the whole matter more accurately, we are forced to conclude that neither one of the three is a reality of the sensible experience we have, but is purely and wholly a creation of the mind, which it may apply to space to some extent, but which is after all neither *a priori* in the mind nor *a posteriori* to fact. They are the result of that quality of mind which refuses to be the sport of the winds of destiny, tossed about in the whirl of phenomena like a dead leaf, and equally refuses to be the prisoner of a granite objectivity, crystallized by the pressure of the eternal ages. The face of the sphinx, whether quarried out of the foundations of the world or moulded out of the flowing cloud, is not fashioned by nature at all, but by man.

There is in geometry, however, a still more striking verification of our thesis. This is the invention of four-dimensional space, and in general of N-dimensional space. Even Aristotle conceived of more dimensions than three, for he concludes that there is no transfer from solid to another kind, similar to transfer from area to solid, and Ptolemy undertook to deduce this result. Up to the period of the Reformation algebraic equations of more than the third degree were frowned upon as having no real meaning, since there was no fourth power or dimension. But about one hundred years ago this chimera became an actual existence, and to-day it is furnishing a new world to physics, in which mechanics may become geometry, time be coordinate with space, and every geometric theorem in this world is a physical theorem in the experimental world we study in the laboratory. Startling indeed it is to the scientist to be told that an artificial dream-world of the mathematician is more real than that he sees with his galvanometers, ultra-microscopes, and spectroscopes. It matters little that he replies, "Your four-dimensional world is only an analytic explanation of my phenomena," for the fact remains a fact, that in the mathematician's four-dimensional space there is a space not derived in any sense of the term as a residue of experience, however powerful a distillation of sensations, or perceptions, be resorted to, for it is not contained at all in the fluid that experience furnishes. It is a product of the creative power of the mathematical mind, and its objects are real

in exactly the same way as the cube, the square, the circle, the sphere, or the straight line. We are enabled to see with the penetrating vision of the mathematical insight, that no less real, and no more real, are these fantastic forms of the world of relativity, than those supposed to be uncreatable or indestructible in the play of the forces of nature. Exotic orchids of the human mind, brilliant with hues no painter ever saw, perfumed with a fragrance that no chemist can extract, beautiful with a symmetry that no draughtsman can depict, fascinating with suggestions of undeveloped powers of the human soul, the creatures of this world have shown man definitively that he is superior to space and time and given him a freedom that is beyond even his highest dreams.

Again, with forceps whose delicacy is infinitely greater than that of the tools of the most skilled workman, the mathematician has put together points like glittering beads, on golden wires whose curve is nowhere viewed with the physiological eye, for these curves may have nowhere a definite direction, they may occupy every point of a square area, they may leave empty positions on the wire infinitely numerous, they may even leave every bead at a finite distance from its neighbor and yet occupy every position, they may have direction, but yet nowhere have a definite curvature—in short they are of such intricate workmanship that it is impossible to deduce their properties by inspection. No physiological experience ever furnished any knowledge of these delicate jewels, no brain-cell or ganglion is their case, yet they are among the finest ornaments of Mathesis, Sophiæ Germana. The creation of lines of this type, or from an analytic point of view, of functions of this type, whose properties are not only not intuitively evident but in many cases are directly contrary to what one might expect intuitively, is another indubitable example of the fact that mathematics creates its objects and studies them with an internal eye whose analyzing power is increasing day by day, beyond all limits of light-waves, or intra-molecular structure, beyond all imagery, with more certainty, however, than even the best physical apparatus can enable the physicist to handle the invisible, intangible, and unperceived ultra-violet or X-ray.

We might proceed to inspect other divisions of mathematics and should find always the same conclusion. In every direction in which we might travel we should always come to the vague, the chaotic, the tangle, the unformed, but under the magic wand of the mathematician we find the vague assuming form, the chaotic appearing in order, the tangle turning into a beautiful lacework, the unformed showing first a line, then a net, then structure. Wherever the mathematician meets nature and follows her suggestions he idealizes the phenomena into something intelligible, he paints a picture of a reality he creates

as having in it a structure which matches the phenomena. Measures are made exact, laws become definite, terms are dazzling with new meaning, formulæ become alive. He comprehends physics in the calculus of variations, this in turn he includes in the functional calculus; he reduces mechanics to geometry and geometry to analysis. He solves problems in phenomenal space by his imaginary space, and calculates real numbers by the square root of minus one. A wizard, nor a sorcerer he, for his results are abiding. He is an artist who molds the phenomenal world into forms of statues and makes even more beautiful figures out of nothing at all. He is like the artist of the Beautiful in one of Hawthorne's inimitable tales, who made a model of a butterfly, so delicate in mechanism, so perfect in poise, as it fluttered around with its purple and gold-speckled wings, that the observers fancied it must be a living butterfly. The beauty faded and the mechanism lost its power on the finger of the skeptical watchmaker, who appreciated only his mechanisms of wheels, it glowed and became vigorous on the finger of the naïve child, it delighted the blacksmith, the builder of engineering structures. When the child clutched it, fancying that the beautiful toy might be his own selfish possession forever, it was crushed into a heap of glittering fragments. The artist placidly looked at the destruction, whence the beauty and the utility had gone forever, undisturbed because he knew that he could at will create even more perfect mechanisms, not because they would be more like living creatures, but because they would be more beautiful. Even though not butterflies, they delighted man more than the butterflies.

III

We turn to the consideration of the theme, what is the real in science? with the meaning of the real in mathematics as a guide to the proper answer to the question. We may begin with the oldest part of physical science, going back twenty-two centuries, to the city of Syracuse, where the conquering hosts of Rome have sacked the city, and we see an enraged Roman soldier attack and kill a dignified old man who has been busy with diagrams and surrounded by mechanical inventions of various kinds—Archimedes, in fact, the founder of mechanics. Him we remember indeed while the names of the Roman conquerors have sunk into a just oblivion. His determination of the gold and silver in the crown of King Hieron is mentioned in many a school reader, and the joyful cry "Eureka" has echoed again and again in the laboratories of the world. He idealized the lever and worked out the properties of this imaginary weightless, rigid, segment of a straight line. Since that first bold substitution of an ideal, axiomatic lever for the bar of wood or iron, mechanics has again and again idealized the objects it meets

in nature and to such an extent that rational mechanics is really a branch of mathematics, while applied mechanics points out how closely approximate the results are when attached to material objects.

A stretch of seventeen centuries follows with little advance, up to Leonardo da Vinci, artist and scientist, who with Stevin of Bruges, begins the development of statics. They were followed very soon by Galileo, the first to conduct extensive experiments for the purpose of bringing his idealized phenomena into close harmony with the material phenomena. We see him dropping shot from the tower of Pisa, rolling balls down inclined planes, counting the oscillations of the chandelier in the cathedral, finally with a flash of intuition announcing that a body in motion will remain in motion, and at rest will remain at rest, unless acted upon by some force, thus creating at one stroke two of the entities of modern physics, inertia and force. Bold indeed from a few experiments, on a few objects, to announce for all the world such laws, and to assert that all kinds of matter possess something called inertia! Inertia and mass were long synonymous, and the scientists soon accepted mass as the quantity of matter itself, whatever its kind. But we have come to see a difference between mass and inertia and we may now ask if an electron has inertia, and what kind of thing inertia must be that it is possessed in common by gold, radium, helium, hydrogen, uranium. Does the nucleus of an atom have inertia, and is the nucleus nothing but inertia? If one were on the moon, or the sun, or the lost Pleiad, would these same things possess inertia? Who knows if a particle moved in a line for billions of years in purely empty space whether would it come to rest, or always move on and on without limit? If the inertia of an electron is only apparent and due to the fact that a moving charge generates a field which retards the charge in its motion, why may not all inertia be of the same character, and thus be as fictitious as the added mass of a sphere moving in water?

The year of Galileo's death was the year of Newton's birth, titanic successor to a giant predecessor. His intuition was even bolder than Galileo's, for he conceived the entire universe as knit together with ideal threads. This ideal object he called gravity, the most universally present force, and the one we are to-day most ignorant about. This mysterious object of dynamics reaches to the uttermost confines of the universe so that the quiver of an eyelash is followed by a shivering of all the particles in the magnificent sweep of creation, yet so tenuous is it that nothing seems to interfere with its passage. The huge ball that carries humanity as well as the crater-rimmed satellite that sends its soft glow down to summer-strewn banks, cast no shadows in space under the stream of this penetrating essence of Newton's mind. The radiation of the brilliant star of day is stopped completely by either of

these, and the long shadow trails for millions of miles like a gigantic crayon which marks every object it touches; the X-ray finds its path even among the molecules of the crystal, yet is finally stopped by all kinds of substance; but this creation of the great genius of mechanics—what shall we say of it? The electron in its dizzy spinning and the stately Neptune in his many-yeared cycle, the sun in his wanderings and the nebula in splendid isolation, all alike are mastered by this immaterial, spirit-like, purely ideal creature. And is gravity a kind of matter? So Le Sage thought, but few would agree with him. Does gravity pull on the electron? Who knows? Newton did one thing whose import was not at first perceived, namely, to lay down a universal law that mass, or inertia we may properly say, is measured exactly by acceleration, and in fact accelerations are the only entities that need enter the equations, inertia becoming a mere numerical ratio. Is it possible then that the rock-ribbed hills, the stately palaces, and the gauze of the comet, all alike, are but such stuff as the mathematician dreams of, and the reality is a ratio? Indeed the modern physicist thinks he has shown that even this ratio is variable, depending upon the velocity of the moving point which has been substituted for the material particle. Gravity is not matter, and inertia is a ratio! But this virtually is saying that the world of mechanics is purely an ideal world, created by the physicist's mind in precisely the same way that Lobachevsky or Riemann created a non-euclidean world. Neither is more real than a cube, and either is real in the same way a cube is real.

Since Newton's day the other conception, force, has been extended to a great variety of phenomena, so that we have had force of cohesion, force of electricity, force of magnetism, force of chemical affinity, force of elasticity, and still others imaginable. Mysterious fingers were at every point in space ready to clutch the appropriate object of their desire, were it particle of matter, electron, magneton, molecule, or atom. The force of gravity was pulling all the time on every one of us to keep us from falling off the earth, the cohesive forces were keeping us from being shattered into dust before our time, the chemical affinities were at work building up the compounds of which we consist, and the tremendous play of these giants struggling against each other throughout the universe preserved us from chaos. They represented a premodern transformation of the nature gods of early history. For the modern physicist has abolished the once real forces, and no longer imagines space as full of the invisible fingers the giants once had. Like the childish dreams of fairies who did things secretly that man could not do, these naïve conceptions of the physicist and chemist have given place to others which are supposed in their turn to represent reality. Is there any better example needed of the creation of an ideal

reality which was relegated to the museum when no longer useful in the handling of phenomena? Inertia a ratio and force expressed completely in terms of change of position in space—the dream of Pythagoras realized in one, that of Heracleitos in the other. Where is the unchanging reality Parmenides asked for? Is it true that we can only say of two dust particles that they gravitate, that is move towards each other, of two electrons that they move away from each other, of atoms in a benzene molecule that they form a stable group, and, though stable, are in an incessant and intricate waltz figure forever shifting its diagram? When a huge charge of nitroglycerine explodes and shatters the surrounding objects, can we say nothing more than that the atoms of nitroglycerine separate under certain conditions in the neighborhood? Is it possible to reduce all physics and chemistry to the calculation of a function of each point in space called the potential of that point, a function depending for its value upon all the points in space where matter or electricity or other object is situated, a function to be determined in all its non-singular points by the position and certain numerical values associated with the position of all its singular points? We have used the gravitation potential, the electric potential, and the magnetic potential, and we might add the chemical potential, as a matter of convenient mathematics, but what if potential is the only reality? At least it is as real as any other conception we have of nature, yet no one has ever thought of it as other than a mathematical term.

The year Illinois was admitted to the galaxy in the blue sky of the American flag, was born the man who should not only revolutionize many of the conceptions of physics and chemistry, but should revolutionize the whole of natural science. Before his time there had existed an imponderable, invisible fluid called caloric, to which was due the phenomena of heat. We still have treatises on the flow of heat, in which the equations refer to a continuous fluid. But the famous experiments of Joule brought forth a new reality called energy and the law of the conservation of energy, said to be the grandest achievement of the human mind. Sublime substitution of the more unknowable for the unknowable! Sublime determination of the one great reality of nature which persists through all the swift transformations of atom, molecule, cell, or universe, from the meanest flower that blows to the most infinite nebula seen or unseen! Energy is that which can neither be created nor destroyed, the great god Proteus, changing in a flash his form so that he may not be recognizable, who may hide utterly so that his presence is unsuspected, yet in a twinkling may let loose his awful power and rend the visible universe. Energy was nascent in the phlogiston of the eighteenth century, for phlogiston was what escaped during the burning of substances, but phlogiston was a substance, and when

it was proved that it had no inertia, it was also stored away with the other models of man's creation as no longer of use. Energy can not be measured, neither weighed, nor seen under the microscope. Its presence can not be detected by an apparatus. Like the velocity of the earth, we know nothing about it directly. It is not involved in any of the phenomena of sense. It is not an inference from the observations nor experiments of the laboratories, such as the velocity of the earth may be. It is a direct creation of the human mind as much as the square root of minus one. When we have ascribed certain physical or chemical changes to the transformation of energy, the residue which is unaccounted for is ascribed to some new form of energy. We invent these forms as we need to make the law of conservation of energy hold good, and we demolish them as we find that we can account for phenomena with fewer forms that energy may take. We observe motion and we ascribe energy to the moving points, kinetic energy, depending upon the square of the velocity. The point may stop and the energy be gone, but then we say it has become potential. We always have an unlimited supply of kinds of potential energy to draw upon. We have potential energy of gravity, the energy a stone on a cliff has because it is on the cliff; the potential energy of an electron, the energy it has because of its situation as regards other electrons; the energy of an electric field, or a magnetic field, both purely immaterial mathematical fictions, is potential; the energy let loose by the high explosive shell that screams over the battlefield was potential energy. But most astonishing of all we may describe mass as merely energy per velocity per velocity. The most unknown reality of nature enables us to define that which we might suppose to be the most known reality of nature. Yet it is not matter that interests the future of the race, but energy. By it we live and move and have our being, and when we can no longer control energy we must perish. Profligate sons of Pan, we gaily spend the stores of energy slowly accumulated by mother earth, nay more we almost deliberately waste the stores of obtainable energy. We see already the darkening horizon of the future when coal will be gone, oil and gas fields exhausted, and we are even now desirous of robbing Niagara of its beauty that the sale of energy may fill pockets with gold. We see many a Swiss valley with a glacier at one end and nitric acid at the other. We build dams like cliffs to utilize the kinetic energy of the white coal, we rob the winds of their store, and we would chain the ocean wave to a treadmill.

We may even go further and say that there is no potential energy, but that all energy is the energy due to motion, even though the moving points may be hidden so that their motion is simply assumed. We have done this in explaining where all the heat energy goes when a gas

receives heat. Some of it causes the molecules to move faster, but some of the heat, and in complex cases much of the heat, becomes energy of rotation of the molecule and energy of the motion of the atoms within the molecule. In fact, if enough heat is supplied the molecules may be broken up. When we come to the atom, however, which is itself conceived to be a system of swiftly rotating electrons with a positive nucleus, we find that heat can not be transferred to it, in fact so far man has been unable to interfere with the structure of the atom. Yet in the case of radium every one knows that we have as unstable a system as a nitroglycerine molecule, and that the atom breaks up by expelling every so often electrons, and every so often helium atoms. The amount of energy let loose in this way is enormous, in fact the whole earth with its volcanoes and geysers, with its earthquakes due to internal explosions, is getting hotter and hotter from the radium explosions within, and the accumulation of energy may sometime cause the entire planet to explode. What kind of a motion is it that can be so vigorous as this, inside the infinitesimal space that an atom occupies? If the potential energy is after all only the energy of these invisible motions, how enormously fast it must be!

In connection with the transfer of energy, as from the sun to the earth, we find the creation of a medium called ether. It seemed inconceivable that energy, if it be only motion, could get from the sun to the earth without anything to move in the interval. At a speed of 185,000 miles per second this medium transmits radiation of all kinds, whether light, heat, or the wireless wave. The auroras of the northern sky due to the magnetic energy that arrives from the sun when some cyclone of terrific power shoots out its winds of intensely hot hydrogen for hundreds of thousands of miles, the ceaseless flow of waves of energy as the electron circles around its nucleus billions of times in a second, waves that impinge upon matter like the waves of the ocean upon a mass of rock, capable of setting matter in motion by their pressure, all these surely need a medium to transmit the energy if it be motion, that is, kinetic. But the modernmost science sees no further need of this medium and it may also be put away with other discarded models the mind has made, for if it does not exist save as a conception, how can it be a reality of any type but mathematical? In fact it is still simpler to consider that energy itself moves in empty space, and that a wave consists of a current of energy that waxes and wanes, rising to a maximum and sinking to zero several billion times within a second. This current of energy has a momentum, which is the quotient of the energy density by the velocity, and a mass, which is the quotient of the momentum by the velocity. Thus an electron is reduced to moving energy, this energy having a central point which it does not

reach, the intensity of the energy varying as the inverse fourth power of the distance from this center, the center being surrounded by a sphere of discontinuity at which the energy becomes zero on one side and a very great value on the other. If it be possible then to reduce all electrons to energy distributed in space in this manner, and all matter to aggregates of electrons, we obviously have come finally to Parmenides's vision of the one substance of being. And we might also say that we have realized Heracleitos's vision of the Fire whose fixed measures are always being kindled and fixed measures going out. What a perfect chaos of change the universe becomes, for at every point we see the streaming energy from an infinitude of centers, flashing through space with the enormous velocity of light and producing at each fixed point such an intricate function of the time that we fail utterly to get any picture of the phenomena! And the rotating electron, so rich in this cosmic matter, which it radiates at every whirl with tremendous prodigality, must inevitably slow down as it loses its energy, and ultimately become stationary, and thus nothing at all, unless from some other blazing center it receive a new life. Besides this there are all the moving clusters of energy traveling through space on their own account, with no such attached discontinuities as electrons. Whether energy is granular or continuous is of little import as far as our problem is concerned, the reality of energy being the only question, and if this reality reduces to a non-substantial energy as the only being then we have a reality whose difference from the mathematical type is not obvious.

We have frequently mentioned the electron and the nucleus, other creations of the human imagination, things we can not ever hope to see, existences which we postulate in order to account for phenomena. The new science of radioactivity has produced these objects. The electrons are of the nature of negative electricity, the nuclei are positive, so that the substance electricity has been put in the museum of antiquated models of thought, and neither the one-fluid idea nor the two-fluid idea of electricity is anything more than a useless mathematical model. When will the day of doom of the electron and the nucleus come, and these too go the way of all such constructions of the intellect? And yet when we see the scintillations of the fluorescent screen near a particle of radium it is very convenient indeed to imagine the terrific bombardment of the high-power guns of the minute atoms as they explode their smokeless powder. A nucleus may be a system, but whether an electron is a single thing or a system we can not imagine, and for the present the model is that of a sphere or an ellipsoid, though upon occasion who doubts that we would cheerfully make it over into a whole solar system? We are just now endeavoring to discover whether we

had better endow the electron with inertia or not, with weight or not? The nucleus seems to carry all the weight of the atom.

The chemist has also had his turn at playing with the toys of mind. His molecules he long ago considered to be a handful of round pearls of thought, which he strung into necklaces for the adornment of Scientia, necklaces which consist of chains, with pendants, fantastic clusters, and other figures so mathematical that the great Cayley studied the whole subject as a piece of mathematics. His pearls have turned out not to be pearls, but to be tiny solar systems, so that Scientia is now adorned with strings of universes. These tiny solar systems contain valence electrons whose attractions and repulsions have replaced the chemical affinities. We need not elaborate on the situation, but we must wonder what the diagram will look like a thousand years from now. He has dispensed with eighty or more kinds of matter, save as a matter of convenient language, and is now describing the eighty or more kinds in terms of a few nuclei and electrons. Perhaps he can dispense with the nuclei if he can imagine an intricate enough arrangement of points to take its place, and let the whole universe be described in terms of energy alone, or of mere granules of ether alone, with high velocities to furnish the phenomena of change. The atomization of mathematics has passed the meridian, but that of science is at its zenith.

When we turn to the phenomena of life, the study of the biologist, we find the realities no different. At present he is endeavoring to his utmost to express all these in the same terms that the physicist or the chemist uses, partly in the vain hope that when they are so expressed he can predict what kind of an animal, whether an elephant, a man, or a bacterium, will be the result of bringing together so many molecules of this or that, and so much energy of this or that type. He sees perhaps that to create magnetism where none existed, all that is necessary is to start an electron or even a mere mathematical line of electric force moving, and presto, the magnetism is at hand; so he hopes to rival this magician's trick with one of his own, and by setting electrons and atoms into some kind of motion, arrive at life. Perhaps life consists of such a combination! It may be that there was first a universe filled with granules of nothing at all, mere points, that moved with the velocity of light in all directions, thus having tremendous kinetic energy, or just energy let us say. Perhaps some of these lost some of their velocity, not for any reason or on account of any cause (for such terms are philosophical and forbidden in science), but they just did. The energy being indestructible, exercised its protean prerogative, and changed its form, becoming potential energy, and the thing that now moved was an electron, moving potential energy. Perhaps these electrons in turn congregated accidentally into systems, some of which turned out to be unstable and broke up, some of which were stable and became what we

call atoms. Perhaps the atoms in their Odyssey found other atoms, and with no cause whatever, they joined themselves together because the combinations were stable, that is, did not break up. Perhaps these molecules, as the æons rolled along, also found certain groupings were not broken up, but persisted, always with the accompanying accumulation of potential energy, the potentiality being merely the fact that they did not break up. Perhaps it was the fate of these multimolecules of the colloidal state in the strange caprices of chance to find that some of their combinations were willynilly stable, and were later to be called cells by the scientists. Perhaps the cells became organisms and living creatures. The living creatures during untold and unimaginable periods of time have themselves become more and more intricate, and some of them now group themselves into societies and nations. Yet somehow in all these wild saturnalia of chance, it seems the steady drift has been to form the more and more complex, the more and more highly organized in which the adjustment of the electrons, the atoms, the molecules, the multimolecules, and the cells, is more and more delicate, but, strange to say, more and more persistent. Yet the biologist must admit, what he is reluctant to admit, that when we get to the complicated process of cell-division we must label some of the energy biotic energy, for it is unlike the previous forms. This ought not to be surprising, for if the mere motion of electric energy in space somehow creates instantaneously a certain amount of magnetic energy, neither being quite statable in terms of the other as to kind, we ought not to be startled if in all this long chain of evolution, there should come some day a further form of energy. Convertible of course into the other forms of energy, otherwise it would not be energy, but yet different in kind. We can not help wondering too what peculiar numerical combination always loaded the dice in the game, so that the *complex* was the inevitable result. In mathematical probability we expect homogeneity to result from the chaotic mixture of any set of points with any kind of velocities, not heterogeneity; and even the second postulate of thermodynamics says that entropy tends to a maximum, which is simply the same as saying that in a big enough chaos, everything tends to homogeneity, mediocrity, a dead level. We feel somehow compelled to think of Maxwell's demon as opening the gates for those motions which tended to complexity, and shutting it to those which tended to entropy. So here is a further element that we must put into our model, the feature of evolution, one that so far the physicist and chemist has no need of. This evolution we must call a creative evolution, because we pass from the less complicated to the more complicated. This creative evolution becomes as much a reality as any of the other things we have mentioned. Whatever we are obliged to use in the construction of our model of the universe is a reality of science.

When we no longer need it, it does not cease to have reality, any more than a cube goes out of existence when we study spheres.

The new feature of the model has been called vitalism, a vague term too much associated with phantasms; and entelechy, a more technical term. Entelechy is not more Hellenic than entropy, and hence we need not be frightened at it. It is the formative character of the living thing, that which tends to produce the complexity. The entelechy of a circle is the line which makes the points of the circle into a synthetic whole and not a mere aggregation of points. Some mathematicians, it is true, consider that a circle is nothing but a series of points; some physicists consider that the aggregation of electrons and nuclei is an atom; some biologists consider that the aggregation of multimolecules is a cell; but the modern theory of functions of lines thinks that a circle is more than its points; and the explosions of the radium atom show that there is a stability which may let go and the mere electrons and nuclei cease to be radium; the organizing power of cells, their reproduction, their self-repair, their storage of energy of various forms, their ability to increase their potential characters, whether of energy, motion, or structure, demand that we put entelechy into our image of the universe. What is entelechy? is no more foolish a question, and no less foolish a question, than the corresponding one, what is energy? When we have a way to measure it, it will be used just as much as energy. And it seems obvious that entelechy will have to start with the electron and the atom.

There is still another series of phenomena which the scientist is obliged to study, and in which he might hope to have more success than in those previously mentioned, for they seem to be so immediately close to him that they are part of him. The phenomena of mind ought to be those indeed which the intellect could lay hold upon and strip to their ultimate reality. But here too we see the same procession of models rather than ultimate realities. We must content ourselves with an imitation, or shall we say that what we can call real is only that which we create, and that the real would not be at all if we did not create it? There once used to be in this science a soul, a subtle fluid or spirit, that permeated the whole man, which persisted even after cells had broken down into molecules, after entelechy had ceased to form. We need not pause to study the progress of philosophy and science which annihilated the soul, or rather put the soul into the museum. Mind took the place of soul, a substitution of a more vague term for the vague term soul. Mind was complex, but it was for a time an aggregate of faculties, perception, conception, imagination, judgment, reason, will, memory; and educational systems to-day preserve these divisions. Mind was also constructed out of ideas, linked together in associations which were indissoluble, a vast Pandora box, which occa-

sionally opened and allowed some of its creatures to escape for a time into the air of consciousness, in groups that were too often made up of as many undesirable elements as desirable ones, but always being stored away again in this ever-accumulating aggregate of experience. Mind was later merely an aspect of the central nervous system, and the model became that of the net of nerve cells and their neurons and dendrons—a very mechanical model, and one most facile in "explaining" the phenomena of psychology. If the system split into two sets of cells, isolated from each other, then there were two minds, two personalities in the same body. This model too went its way, to the museum, and the new model was a stream, the everlasting flow of Heracleitos. Like the wraiths of morning mist on the mountain lake, fading away from sight even as they come into view, the wisps of the processes of consciousness are vanishing even as they appear. Just as the biologist might consider that life is merely a series of secretings, circulatings, respirings, digestings, this model of the psychologist's making is only a sequence of happenings. The dream is only the dreaming, the symphony only the playing, the ache only the aching. Like Prospero's magic everything disappears with the thinking. In conclusion we have one more model of mind, which preserves its stability, its entelechic organization of experience into personality, its directive and selective character, its purposiveness, and adaptation of means to an end. Mind becomes a creative agency, and its evolution from the void into the determined, undaunted creature of to-day becomes the story of the universe. Tense with activity, from its bonds it creates spaces and times, from the universe worlds of intellect, from star-dust Pleiades; it makes the winds of eternity carry its wings, it floats on the waves of the stream of phenomena; it touches matter and energy, life and mind, and the Queen of Beauty steps forth, never to sleep again; it plays on the pipes of Pan, and circling electron, blazing Sirius, throbbing cell, and wandering creature, burst forth into music; to intellect it adds intuition, to understanding sympathy, to contemplation creation. No longer does the tantalizing search for the reality of the swiftly fading vision it once had by its flickering waxlight continue, for Psyche has become a goddess, and beholds Eros forevermore.

"MEMBERS ONE OF ANOTHER"

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EVER since the beginning of the war in Europe, the rest of the world has seen what marvels the cooperation of practically all citizens can accomplish at least in the matter of man's control of his environment. The significance of this, I believe, is not far to seek. It lies in the strong probability that man has evolved not so much as an isolated individual as a part of a greater organized group which the Germans worship as the state, but which I feel inclined to call simply the human association in order not to prejudice my cause before getting under way. When we say that man or the horse or the lobster has evolved, we ordinarily think of the evolution of the individual man or horse or lobster. But, while you and I have been evolving, there has been going on another kind of evolution, less obvious, but quite as important. The evolution of the whole body means the evolution of cells and organs, but the cells have been evolving in order to perfect the individual and fit it more completely to its environment. The individual organs lose their independence but the society of cells and organs is better fitted to survive. You and I have been the objects which are fitted to survive in the struggle for existence and not our eyes and teeth and stomachs. But, as we shall see later, in some cases it is evident that the individual animal has not been the unit which has been best adapted to its environment, but a group of individuals which survives in competition with other groups. The association of animals may be the evolutionary unit quite as truly as the individual; in the same way that the individual body is the evolutionary unit rather than the specialized organs and cells making it up. The question I would raise, then, at the outset, is, has man evolved as an individual or as a part of an association? Are we "members one of another," as the Apostle Paul seemed to think, or are we individuals having no relation to our fellows and answerable to no one, after the fashion of Nietzche's supermen?

The problem is readily seen to be far-reaching. Its bearing upon our social and political organization, religious beliefs and moral code is intimate. In the light of human evolution, is humanity destined to become more closely socialized or less so, is individual effort to become more or less individual in its returns, are national boundaries to hem their citizens in more tightly or are boundaries to break down eventually? It would be manifestly impossible within the scope of a single paper to touch upon these far-reaching problems. I would attempt

something far less comprehensive and simply point out some of the traits of man's immediate ancestors and what seems to me to be one of the most important factors which have brought about his evolution.

Before considering the evolution of the human race, one or two phases of the general phenomena of evolution must be discussed, for without this explanation the more specific problem of man's evolution will not be so clear. Evolution results in greater adaptation to environment, in bringing the individual into a more intimate relation with the world outside itself, or in giving it more abundant life. Adaptation, or fitness for a particular niche in nature, has been the end of evolution, for extinction has been the fate of those forms which do not fit into their place in the world and which succumb in the struggle for existence. In general, this adaptation has been effected by specialization of parts with division of physiological labor, and therefore greater interdependence of parts. But there are numerous instances, especially among parasites, in which the course of evolution has been in the direction of degradation of structure and loss of specialized organs.

The Protozoa with their generalized structure and activities lost the capacity of independent life as soon as they began to form a Metazoon. Each of the generalized cells constituting a Protozoon has all the general functions of the most complete animals; each cell can take in food, digest it, assimilate it; each cell is responsive to changes in the environment, such as changes in light, temperature, density, and chemical composition of the surrounding medium; each cell grows and reproduces itself when the limits of growth have been reached and takes on a new lease of life by the act, an immortal bit of protoplasm. As soon as cells, however, begin to be specialized, the activities are curtailed, so that some become far more evident than in the generalized Protozoa. In the simplest Metazoa, like the freshwater *Hydra,* certain cells become specialized to digest food, but lose their power of movement, while others which come in closer contact with the environment—those covering the exterior of the body—become more resistant to mechanical disturbances and more capable of movement. Each group of cells making up the *Hydra* has lost some of its primitive functions, but has become more alive by association with other specialized cells. With further differentiation, the activities of the different organs become more circumscribed, so that here the power of secretion is lost, there the power of movement, and in another organ irritability to this or that form of stimulus—our finger tips are not sensitive to the perfume of the rose, nor our ears to its color.

The cells which were, in the very simplest types of animals and plants Jack-of-all-trades, can not exist, when specialized, apart from their fellows, which all contribute to the general welfare of the whole. "The eye can not say to the hand, I have no need of thee; or again, the

head to the feet, I have no need of thee." The perfection of the eye is possible only because the needs of this organ are supplied by a great variety of other parts. We can only smile heartily over the naïveté of Empedocles of Agrigentum, who may be called the father of the evolutionary idea, who thought that animals first appeared, not as complete individuals, but as parts of individuals—heads without necks, arms without shoulders, eyes without sockets. We are forced to regard the eye as evolved not as an independent structure, but simply as a part of a whole organism. The needs of the whole organism have been more perfectly met as a result of the specialization of the parts, and not the separate needs of the individual parts. Everywhere an evolution of separate parts in order that the individual organism may be better fitted to its environment has been going on. The brunt of evolution has been borne by the individual and not by the separate organs. Have we any indication in nature of larger organized beings than the individual person, namely communities or colonies which have borne the brunt of evolution and which have evolved at the expense possibly of the individual parts composing them? Is the relation of the individual man to the association comparable to that of an organ or cell to the body?

There is, of course, a certain biological similarity between the individual organs of the body and the body politic, as Thomas Hobbes developed as early as 1651 in his book, "Leviathan," and which has been discussed by many others more recently, notably by Herbert Spencer. The organs are masses of material specialized to perform certain functions which extend the life of the whole body and are mutually dependent on each other. The society and the individual body both grow from small beginnings which exhibit no specialization at first, and gradually attain greater and greater specialization and interdependence of parts. The similarity between the organs or cells on the one hand and members of an association on the other is heightened by the fact that there is a certain competition or opposition among the cells just as there is among the citizens of a healthy state. The gymnast's arms grow and become strong while his legs and brain may remain feeble, because the limited amount of nourishment which the body is able to absorb is diverted to the arms. As Ernst Haeckel says in the opening chapter of the "Riddle of the Universe,"

> We can only arrive at a correct knowledge of the structure and life of the social body, the state, through a scientific knowledge of the structure and life of the individuals who compose it, and the cells of which they are in turn composed.

Interdependence of parts and the exchange of the products of their activity, which has been called the vital circulation, are the criteria of an organism. Just as soon as the products of metabolism of one layer of cells are transferred to another layer, or as soon as food procured by one member is transferred to another, just that soon an organism results.

There are several obvious objections to the idea that the evolution of man has been as a member of a group rather than an individual, or that the relation of a man to the group in evolution has been that of an organ or a cell to the body. The loudest objection, possibly, is on the basis of the ignoring of that preeminently human trait, individual consciousness. Consciousness resides in the individual person and can not be united into a common consciousness resident in the group, but until something more definite is known regarding the nature of consciousness and the occurrence of consciousness in the lower animals, is does not seem possible to take it into consideration on a purely scientific basis.

A further objection to the thesis here presented is that while the organs of the individual body are necessary for the health of the individual, the human association finds no one individual essential for its continued health and prosperity. This objection, however, is not as valid as it appears at first hand because the comparison is invariably made between the individual composed of many highly specialized and stable organs and the association in which biological specialization, in contrast to social specialization, has been carried to a very slight extent. The discrepancy becomes rather negligible when comparison is made between a simpler, only slightly differentiated, individual and the association. Thus, the simple freshwater *Hydra* made up of two layers of cells is so plastic that it may be turned wrong side out by proper manipulation with no serious injury. In other words, although there is mutual dependence between ectoderm and endoderm and both make up the individual *Hydra's* body, both are so plastic that the one may be transformed to the other under proper stimulus. Or again the individual body of one of the higher animals may be subjected to the loss of many of its cells without suffering in any way. Portions of some of the most vitally necessary parts of the body may be removed without causing inconvenience. The idea of an individual organism, then, does not exclude the possibility of a single part's taking over the functions of others and adjusting itself to the new conditions.

As will be shown presently, more perfect adaptation may involve the single individual or it may involve the whole group or colony of individuals. In general, of course, the welfare of the race means the welfare of the individual, and the injury of the individual means just so much loss to the group; but there are some striking exceptions to this rule which may throw some light upon the problem of human evolution. In these cases the fittest which have survived are not the fittest individuals but the fittest colonies, or groups. Fitness may indeed have been achieved at the expense of the individual. The associations which show most clearly the specialization of the individual for the adaptation of the whole group are those of the lowly Hydroids and the highly specialized social bees and ants. The Hydroids are marine animals having

a plant-like appearance which abound usually in shallow water firmly attached to some solid support and covering extensive surfaces often with a furry growth, very closely related to the coral polyps. The colony is made up of countless polyps branching from each other and connected by a continuous system of hollow tubes which adhere to the solid substratum and afford communication between the separate polyps. Generally these are all alike and are able to take in food, to digest it, to throw off powerful stinging organs when stimulated, and to reproduce their kind by sending out buds like themselves, but they are incapable of locomotion. If the colony is divided, each bit is perfectly capable of continuing its existence indefinitely for each polyp is self-sufficient. From time to time, however, a different kind of individual is produced, known as a medusa, which swims away and lays eggs, but is incapable of taking in a particle of food and so is doomed to an early death. Each medusa is dependent upon the polyps for food, and might, if it did not break away from the family, be regarded simply as an organ of the more complex colony. The medusa has evolved for the extension of the colony; its own continued existence is sealed. It is the colony as a whole which has evolved as an adapted organism and not the individual polyp or medusa; just as in the bodies of the higher animals it has been the individual rather than the single organ which has borne the brunt of evolution.

An even more striking illustration of the evolution of a whole colony is afforded by the Portuguese man-o'-war, a near relative of the hydroids. In these animals the colony exhibits a permanently continuous group of individuals of various kinds, but each specialized for a particular function and evidently built on the same general plan and evolved from a less specialized form of polyp. The Portugese man-o'-war is made up of groups of defensive, nutritive, reproductive, sensory, and locomotor individuals which, unlike the hydroid polyps, have lost their power to live independently but which have been so closely united as to form organs of a single body. At the same time the structure and development of these different polyps shows beyond the shadow of a doubt that they are in reality different forms of the same individual polyps of the Hydroids.

Finally there is the case of the social bees and ants in which the social unity is so definite and perfect that the individuals are incapable of continued life outside of the colony. The queens are usually so specialized as to be incapable of procuring food and rearing young without the assistance of the workers and the workers in turn are so specialized as to be incapable of reproduction, and the drones are indisposed to exert themselves in foraging. "Associated animals," says Darwin, "have thus acquired many remarkable structures, which are of little or no service to the individual, such as pollen-collecting apparatus or the

sting of the worker bee, or the great jaws of the soldier ants." The instincts no less than the structure of the different castes of social insects are distinctly social and can not possibly have come into being except in so far as the colony has evolved as a unit rather than the individual. It is difficult to see how the instinct to sting an intruder could have been developed directly, in view of the fact that in most cases it results fatally to the bee. It is also difficult to see how the instinct to lay up food for months could otherwise have developed in an animal whose normal life is only six weeks. The different castes of ants furnish equal evidences along this same line of the direct evolution of the colony or association and the indirect evolution of the individual. Thus in certain species there are workers and soldiers with jaws and instincts more different than in unrelated species. The workers of one caste never leave the nest but are provided with food by another caste. In all these cases a division of labor is effected which is advantageous to the association of ants as division of labor also is to human beings, enabling a much larger population to be supported on a unit of surface. Complete interdependence of parts and the transfer of material from one part of the association to another indicate a very closely knit association which has been differentiated by an evolutionary process operating through the community, and not through the individual. Although made up of discontinuous masses and lacking permanent form, we must, I think, agree with both Wheeler and Julian Huxley in regarding the swarm as an organism, the product of a complex evolution.

It is perfectly evident, I think, from what I have just shown, that some organisms have developed because of the operation of the evolutionary process upon their individual bodies directly, while others have developed as subordinate parts of the whole group which has evolved as such. Of course, we can not tell why one species should evolve as individuals and another as an aggregate, but that such is the case there can be no doubt.

This shift in the brunt of evolution from the individual to the group in mankind would seem to explain the difference which Huxley made so clear in his essay on "The Struggle for Existence in Human Society."

> Society differs from nature in having a definite moral object; whence it comes about that the course shaped by the ethical man—the member of society or citizen—necessarily runs counter to that which the non-ethical man—the primitive savage, or man as a mere member of the animal kingdom—tends to adopt. The latter fights out the struggle for existence to the bitter end like any animal; the former devotes his best energies to the object of setting limits to the struggle.

In order to determine whether man's evolution has been as an individual or as a part of a group, the most important respects in which

man differs from his nearest allies among the beasts must be considered. The most essential differences between man and the apes are the upright position and general defenselessness of the body, the enormously developed intelligence with the power of speech, and a moral sense. In how far these traits are quantitative and not qualitative does not concern us here.

In comparison with the rest of the animals, the relatively weak and defenseless body is striking, especially in view of man's size which renders him unable to retreat into recesses too small for his aggressors, after the fashion of so many of the weak and defenseless gnawing mammals. Man has no defensive armor or heavy integument like the armadillo or elephant, or heavy hair to afford protection against claws and teeth. In fact, the upright position renders man especially vulnerable, although it frees the hands for the wielding of clubs or stones. The smaller base made by the two feet instead of four and the elevation of the center of gravity render man particularly easily overthrown in combat. Besides, some exceedingly vulnerable parts of the body which in the four-footed animals are protected by their position, are left exposed. The whole trunk, with its broad, flat thorax and with the abdominal organs without even a bony chest enclosing them, is especially liable to disabling or fatal injury. In addition, the superficial position of the femoral artery in the groin due to the straightening of the thigh on the hip must have been responsible for much human wastage since prehistoric time. The upright position has likewise rendered the carrying of the fetus particularly hazardous and has put such a strain on the veins of the lower extremities as to make them liable to become varicose. Weak as the human body is against attack, it is almost equally weak in offense; large teeth or strong talons, or limbs of such a shape as to be strong in relation to their weight are not part of the human equipment. Man's strength and survival in competition in nature must be attributed to his intellect and social solidarity. It has only been by man's standing shoulder to shoulder and cooperating for a common purpose that he has gained ascendancy over the beasts and become superlatively intelligent with the power of speech and a moral sense.

The biological approach through the structure, embryology, and fossil remains of the ancestors of the human race do not shed much light on the question whether or not man has evolved as an individual primarily or as a part of an association.

From the psychological avenue of approach more light is thrown upon our problem. The habits of the apes, especially the less specialized ones, those which more nearly represent the common ancestor of the human race and the larger anthropoid apes would seem to indicate a gregarious habit in man's primitive ancestors. It is only the larger

anthropoid apes like the gorilla and the orang in which the habit approaches the solitary, and these forms have very restricted ranges which would seem to indicate that they are disappearing. If man did not evolve as a part of a group, if the group were not the unit which was perfected for the struggle, much of the peculiarly human psychical activity has no meaning. The moral sense and the power of speech, man's most distinctly human possessions, could not easily have come into being apart from a social life in a community of interdependent parts.

Darwin has summed up the evidence regarding man's ancestors as follows:

> Judging from the habits of savages and the greater number of Quadrumana, primeval man, and even his apelike progenitors, probably lived in society.

Darwin even went so far as to suggest that man sprang from a comparatively small and weak species rather than a powerful one like the gorilla since it would have necessitated the development of social qualities which led him to give and receive aid from his fellow men.

> An animal possessing great size and strength and ferocity, and which like the gorilla could defend itself from all enemies, would not perhaps have become social; and this would most effectually have checked the acquirement of the higher mental qualities such as sympathy and the love of his fellows.

The moral sense is a natural and inevitable development from the social instincts and would have been acquired by any animal endowed with well-marked social instincts, including the parental and the filial affections, as soon as the intellectual powers had become as well developed as in man. As Darwin has shown, the social instincts lead an animal to take pleasure in the society of its fellows, to feel a certain amount of sympathy with them and to perform various services for them. Horses and cattle are known to lick and nibble each other in smoothing their coats, and monkeys are prone to help each other to remove vermin from inaccessible parts of their bodies, and in some instances it has been observed that they remove burs and thorns from each other. Then, as soon as the mental faculties had become highly developed, images of all past actions and motives would be passing through the mind of each individual and that feeling of dissatisfaction which invariably results from any unsatisfied instinct, would arise, as often as it was perceived that the enduring social instinct had yielded to some other instinct. And still later after the power of language had been acquired, the common opinion how each one ought to act for the public good would naturally become in a permanent degree the guide to action. In other words, the social instincts are the necessary and sufficient conditions for the evolution of a moral sense.

Alfred Russel Wallace expresses the same truth as follows:

> The moral sense in man has developed from the social instincts and depends mainly on the enduring discomfort produced by any action which excites the general disapproval of the tribe. Thus, every act of an individual which is believed to be contrary to the interests of the tribe, excites its unvarying disapprobation and is held to be immoral; while every act, on the other hand, which is, as a rule, beneficial to the tribe, is warmly and constantly approved, and is thus considered to be right and moral. . . . The social instincts are the foundation of the moral sense.

The moral sense has no significance from the point of view of the individual, but only from that of the larger association for

> although a high standard of morality gives but a slight or no advantage to each individual man and his children over the other men of the same tribe, yet an increase in the number of well-endowed men and advancement in the standard of morality will certainly give an immense advantage to one tribe over another. A tribe including many members who, from possessing in a high degree the spirit of patriotism, fidelity, obedience, courage, and sympathy, were always ready to aid one another, and to sacrifice themselves for the common good, would be victorious over most other tribes.

Furthermore, no tribe could hold together if murder, robbery, treachery, etc., were common within its limits.

Thus it would seem that the presence of a moral sense in man presupposes a group intimately associated, and more or less interdependent, and that the evolution of a moral sense results in the better adaptation of the group rather than of the individual. One of the few really distinguishing features of the human race, morality, could not have evolved had there not been the necessity for an association of mutually dependent individuals.

Together with a moral sense, the power of speech distinguishes man from the lower animals. And just as the social habit was necessary for the evolution of morality, it was absolutely essential for the development of language. It is scarcely necessary to indicate so obvious a relationship. It has the same function in the community that a nervous system has in an individual body, for, by means of it, different parts of the organism are brought into relationship with each other and a change in one part is transmitted to a widely different part for the accomplishment of some purpose by the larger group. Just as the nervous system unifies or integrates the individual body, language brings the association into harmonious action. As Professor Sayce has said in his "Introduction to the Science of Language," "Language is the creation of society."

Once the human species ceased to be *Homo alalus,* the stimulation of one part of the social organism called forth action in a different part and the whole association was knit more firmly together and *Homo sapiens* appeared on the scene of action. Language also allowed memories to be passed on so that there might be a storage, as it were, of

impressions to be released by the association at a subsequent time. Man acquired the power of directing actions within the association at a distance both of time and space and these two troublesome conceptions were to a certain extent overcome. As soon as men had to live together, and found that they could by making signs direct each other's actions, there was immediately an immense step made forward in the arrangement of propositions within our brain, as Professor Clifford has expressed it.

This very brief consideration of the way humanity may have evolved shows how fundamental the association of human individuals has been in that evolution, and how fundamentally unified a group of men must have been in order to survive. What constitutes a human association I have not discussed. It might be a single family like the Swiss Family Robinson, or a tribe, or a nation, or the entire human species. The limits can be determined only on the basis of interdependence and the so-called vital circulation. In the infancy of the human race it must have been the troupe occupying a restricted region between the members of which some division of labor and mutual aid must have been practised, at least to the extent that sentries to warn of approaching danger and signal the rest of the association may have been set, or one member may have acted as leader and directed the flight from the enemy or spied out food and shelter. However limited the association may have been in the beginning, it is needless to say that now, thanks to the greater intelligence of the human species, the association is wider as measured by the much greater interdependence and much more general vital circulation. When the failure of the wheat crop in India or floods in China raises the cost of living all over the world, and the murder of the Austrian Archduke Ferdinand in the capital of Bosnia sets men murdering each other not only all over Europe but in the heart of Africa and on the shores of Asia, it is evident that the vital circulation now embraces a considerable group.

THE RUSSIAN VILLAGE AND THE WAR

By ROBERT E. BLAKE

PETROGRAD, RUSSIA

THE average Russian village is hardly an attractive spectacle. One emerges from the forest into long, alternate strips of rye, potatoes, flax and hemp; then on the low hill in front, gray cabins and barns appear. Partly ruined and dilapidated, partly fresh and sheathed with clapboards, the houses are scattered along the line of the rut-eaten road. Encircling the shanties runs a high six-rail fence.

This is an important feature of the village, for each "court" (peasant house with outbuildings) is obliged to maintain a given section of it. Within its limits the stock are allowed to wander at will until the crops are gathered, when they are turned into the fields.

In the northern districts the shortness of the season prevents much cultivation of vegetables. The individual peasant, aside from his inherent conservatism, fears his neighbor's children. "What is the use," he asks, "of planting carrots and beets, when they will be stolen before the roots are really set?" Further south, vegetable gardens become more common. The turnip alone, the most hardy of the esculents, is grown in quantities for human and animal consumption.

The inhabitants of the village are seldom picturesque. The costumes of the men—coat and trousers of cheap woolen stuff; occasionally also of home-woven linen of a dull blue color—has no specific character. The women are clad in cheap gingham gowns; only the bright bandanna handkerchiefs give a touch of color to the landscape. The hard life, coarse food and the demon vodka have bowed the figures and lined the faces.

For one who looks below the surface, however, and has some knowledge of the conditions of Russian life, the sayings and doings of this apparently uninteresting hamlet are of profound interest. Russia is an agricultural country, and it is such humble hands as these which raise the millions of tons of grain formerly poured into the mouths of hungry Europe. It is the strong arm and patient heroism of the Russian *muzhik* which form the impenetrable ring of blood and steel which dams the Teuton flood on the western border. For this reason it is not without interest to review those changes which the war has introduced into the life of this isolated settlement, which was previously almost untouched by the currents of the outside world.

Should we happen to visit the settlement at harvest-time, we should

be struck by the predominance of women over men among the field hands. A husky *baba* (peasant woman) is hooking the hay on to the cart: two more are trampling it down. In a neighboring strip of rye an old, bent woman is swiftly and scientifically binding sheaves of golden grain which fall before the sickles of her two half-grown grandsons. Further on two young peasant women are pulling flax, knocking the earth by a dextrous slap upon the brown instep, only pausing to cast a bright eye in the direction of the travellers as the "phaeton" gallops by. It is the broad-shouldered, wide-hipped Russian *baba*, whose husband and sons have left her to shed their blood for their country on the plains and in the swamps of Poland. Bowed already by household cares, she has taken upon herself the labors of her absent men, and her strong arms, equally at home in the field and in the house, now do the plowing, sowing and reaping as well as spinning, cooking and rocking the baby.

Of course, she works under a handicap. About 40 per cent. of the draft animals have been requisitioned for the needs of the army. This has had its effect in the reduction of the total area under cultivation, which probably averages about 15 per cent. in those districts of Russia which lie outside the immediate zone of hostilities. The peasant is better off in this regard than the landholder, for the communistic organization of the village enables the available resources of stock and of labor to be more evenly distributed over the territory under cultivation. The government has helped as well by the advance of seed-grain, and to a certain extent by placing the services of the prisoners of war at the disposal of the population.

One thing has improved the situation greatly. Vodka, the curse of the population of Russia, has disappeared. The green sign of the *kazyonka* (vodka-shop) has departed for ever. This does not mean that Russia has stopped drinking—shades of Bacchus, no! There is hardly a peasant's hut in North Russia which has not three or four hop-vines growing near by, and every peasant woman knows how to brew *braga* (home-made beer). The townspeople comfort the inner man with wonderful and awful mixtures, whose basic components are furniture polish, denatured spirit and eau de cologne. But (and it is a very large but) these compounds to not penetrate to the remoter villages, and even if the population does indulge in a keg of beer now and then, the crops are not turned into alcohol as was the case before the war. One illustration from the writer's personal experience will show the far-reaching consequences of the measure. In one miserable village in northeastern Russia the income from the vodka-shop had been 23,000 rubles ($12,160) a year. There were 23 "courts" in the hamlet, which made the average outlay per group of families (married sons live with their parents) something over a thousand rubles a year. Granting that

the exigencies of war-time have increased the disbursements of the family to a very considerable degree both in living and in working expenses, yet one can easily understand why the bank-deposits of the small investors have increased at the staggering rate of five million rubles a month.

The cyclonic wave of refugees which swept over the eastern provinces in the late summer and fall of 1915 brought another serious problem before the Russian village. A satisfactory solution of the same was reached only by the united work of the government and of all classes of society.

The lack of ammunition had made it impossible for the Russian armies to withstand the German drive on Poland. Foot by foot, contesting stubbornly, the legions of the Tsar were forced back from the Carpathians to the Vistula, and the San, from the San to the Dvina and the Pripet. Realizing that for the enemy supplies were the essential thing, the Russian decided to remove the population from the districts which they evacuated. Houses, crops and untransportable household goods were systematically burned. The unhappy inhabitants of the western governments were despatched eastward, taking with them their stock and sometimes a few of the more valuable chattels, but in many cases having to abandon them *en route*. More often, alas, they were forced to flee, having only had time to destroy, but not to save. This tidal wave of unfortunates swamped the railroads and the larger towns for the better part of three months. Official figures give the sum as four millions, but this is unquestionably too low. When we count those who left before and make allowances for faulty registration, etc., eight millions will not be far from the truth. To properly conceive this staggering total is almost impossible for the human mind. The ghastly amount of suffering and hardship which it occasioned can only be grasped by those who themselves beheld the arrival of the refugee trains: only those who aided and assisted can know the hell through which these human beings had passed.

The overcrowding of the larger towns brought about an immediate rise in prices of food and lodgings, especially for the poorer classes. To reduce the resulting congestion, it was decided to quarter the surplus population on the villages of the eastern governments of the empire. The relatively speedy and well-arranged distributions of the refugees was carried out largely through the efforts of the two great public organizations, the alliance of the *zemstva* (the local non-municipal self-governing bodies, best to be compared to the county governments among American institutions) and the league of Russian municipalities. They have shouldered a large share of the burdens which the war has brought upon the country.

With the arrival of the refugees serious complications arose for the

Russian village. In the first place, the unfortunates received a pension from the government, which was sufficient to provide them with the bare necessities of life. Such being the case, they were by no means inclined to exert themselves in the fields. Secondly, the majority of them were women and children. The Russian *baba*, as we have described above, can work in the fields as well as a man. This is not the case with the inhabitants of Poland and Lithuania. If extra hands are needed there in the fields they are hired. The women occupy themselves at household tasks or peasant industries—weaving, embroidery and the like. Thus the intention of the government, which had aimed at utilizing immigrants to help out the situation, was baffled, and the expected benefits did not materialize. The arrival of the refugees, apart from the above, had one serious economic consequence, which was felt most oppressively by the peasants themselves. The payment of the subsidies by the government to the refugees brought a considerable amount of ready money into the outlying villages. This caused a sharp rise in prices on food, the burden of which fell upon the peasants. The result was a widespread dissatisfaction, and to the same the government was forced to devote its most serious attention.

When we take it all in all, it seems to the writer that the Russian village has withstood the test of war conditions remarkably well. Part of the credit for this is due, no doubt, to the communistic basis of the land ownership (the *mir*). This has enabled the peasants to distribute their burdens more equitably, and has maintained a higher productive level. This is the more remarkable, when we remember the low percentage of literacy which prevails in Russia. One hears very often that the Russian peasant knows but little about the war. This is to a certain extent correct, for news penetrates slowly to the outlying hamlets. He is vitally interested in the war, however; there is hardly a family throughout the empire which has not one or more of its members in the field. No matter how ignorant your peasant or your *baba* may be, the fate of their nearest and dearest is a matter of vital import, and such news as penetrates is assimilated and comprehended—though perhaps partially and incorrectly—by each recipient according to his or her mental development.

Should it then come about, as all true Russians believe and hope it shall, that the Germans will be defeated, the glory will not be the guerdon of the valiant peasant alone, who has dyed with his blood the treacherous swamps of Poland and the rugged passes of Armenia, but an equal share must likewise be given to his patient and hard-working wife and mother, who cultivated the fields and cared for the children behind the bulwark reared by their husbands and fathers.

FLORA OF THE VICINITY OF NEW YORK

r NORMAN TAYLOR

.BROOKLYN BOTANIC GARDEN

IN 1749–1751 Cadwallader Colden, lieutenant-governor of New York and correspondent of Linnæus, published the first flora of New York and vicinity. It was a list of the plants as observed by himself and his daughter Jane Colden, growing near their home in what is still called "Coldenham," Orange Co. Written by a man who wrote to Gronovius that "botany is an amusement which may be made greater to the Ladies who are often at a loss to fill up their time," it well reflects the attitude of his period. As a historical record the list is valuable. As a forecast of the modern position of botany or women, his remarks are commended to botanists and to those feminists who find it difficult to "fill up their time."

Not until 1819 was there another list of this importance, when John Torrey published his "Catalogue of Plants growing Spontaneously within thirty miles of the City of New York." This was a book of 102 pages and listed hundreds of species and varieties, some of which are now rare or extinct near the city. To touch only the high spots of a long historical record, mention should be made of Leggett's "Revised catalogue of the plants, native and naturalized, within thirty-three miles of New York" (1870–1874) and the "Preliminary Catalogue of Anthophyta and Pteridophyta" reported as growing spontaneously within one hundred miles of New York City by Britton, Stearns and Poggenburg (1888). Some of these lists contained notes on the distribution of the species, but in most cases only lists of plant names were possible. The outstanding character of them all, as in the beginnings of most science, was that they were chiefly records of facts. They were the culmination of our forefathers' study of the local flora, arranged in orderly fashion, which at that time was all that could be done.

It is impossible to talk about the vegetation of New York without knowing very definitely what are the units of that vegetation, and it is the chief legacy of this older generation of New York botanists, that they have handed down to us so complete and so accurate a record of those units, as they knew them. There were, of course, hosts of minor efforts covering the region near the city, or parts of it, about which nothing can be said here, except that like the more important works their object was simply to record the facts. It should not, however, be implied that these workers lacked a larger vision which should seek to explain or correlate their patiently acquired facts. For we find in July, 1870, a forecast of what they were striving for, when in

the *Bulletin* of the Torrey Botanical Club there appeared in an account of the floral regions of that area, the statement that

> Any rational catalogue of our flora should distinguish what plants are absent from or peculiar to each natural region and should contain such information in reference to soil, climate, etc., as may help to elucidate the distribution.

Among purely local botanists, this was, I think, the first statement implying causation that had appeared. Gray, Torrey and Hooker had all written extensively of the flora of North America, and some of them, at any rate, had written on the larger problems of the origin and distribution of the North American flora. For the region about New York, with its variety of conditions, there seems to have been no opportunity until quite recently to attempt to fulfil the hope of the writer in 1870 who is quoted above.

Recent studies of the flora show that there are about 2,600 different species of flowering plants and ferns known to grow within, roughly, 100 miles of the City. Of these 85 are ferns and their allies, 23 are conifers and the balance is made up of our ordinary flowering plants. Of the total flora some 613 species have been introduced from outside the area, by man or otherwise, leaving slightly more than 2,000 species of native plants in the region within one hundred miles of the City.[1]

It is a matter of common observation that these plants are not generally distributed throughout the region. In traveling from the Catskills to Cape May, the northern and southern limits of the area studied, we see a variety of plants found in one or the other of these widely separated localities, but not in both of them. Many species find their outposts of distribution near New York. Some appear to have come from the North or South, a few from the West, others are apparently endemic in the area, and this great quantity of forms, the apparent chaos of it all, raises many questions. What is the real composition of our flora, whence derived, and above all how did it reach its present luxuriance and beauty? The attempt to answer these questions necessitates a review of the causes that have influenced the origin and distribution of our native flora.

For all practical purposes the agencies affecting the distribution of our native plants may be divided into edaphic and climatic ones. Under the first must be considered all questions of the relation of the vegetation to the soil and available water supply; or more simply stated the geological factors of distribution; under the second the relation of the flora to climate must be the chief concern.

From the point of view of plant distribution the last geological phenomenon is the most important, as the continental glacier the fringe of which stretched through Long Island, Staten Island, northern New Jersey and Pennsylvania, had a profound influence on the migration

[1] *Mem. N. Y. Botanical Garden*, 5, 1–683, 1915.

of the flora existing at that time. It is obvious that whatever the effects of geological eras before the ice age may have been on the then existing flora, this great ice sheet must have obliterated all the vegetation in the region which it covered. All the region north of the southern edge of the continental ice sheet must have started with vegetatively a clean slate, as it were, when the ice receded. What was the edge of the ice sheet is now marked by an irregular range of hills which stretch from Montauk Point to northeastern Pennsylvania. These morainal hills mark the present southerly distribution of many of our species of plants. Over 8 per cent. of our native flora has never been found south of these morainal hills, notably the red pine (*Pinus resinosa*), the balsam (*Abies balsamea*), yellow birch (*Betula lutea*) and *Quercus borealis* among the trees; *Ribes glandulosum*, the shrubby cinquefoil (*Dasiphora fruticosa*), many thorns, the *Rhodora* and *Kalmia glauca* among the shrubs, besides scores of herbaceous plants.

This glaciated part of the range is characterized, too, by the large percentage of hardwood deciduous trees, and by the great number of introduced plants that are found there. Most of our European weeds flourish in the much-cultivated region north of the moraine.

The unglaciated part of the area is mostly occupied by the coastal plain which, on the whole, is characterized by the long sandy or gravelly stretches that are found on southern Long Island and New Jersey. All of the region is geologically the most recent in the area, the surface being largely made up of Tertiary and Cretaceous deposits in New Jersey and over-wash material from the glacier on Long Island. From the standpoint of the botanist the chief thing of interest about the coastal plain is the pine-barren region of New Jersey. This region is so unusual that the ordinary traveler is at once struck with the difference between these sandy stretches of pine-tree vegetation and the richer flora further north.

It has been shown[2] that the pine-barrens occupy almost exclusively the Beacon Hill formation, in New Jersey, which has been uninterruptedly out of the water since upper Miocene time, and has been several times partly, or wholly, surrounded by sea water. Because of its continual emergence it is the oldest region in our area that can have been continuously covered with vegetation. For the region surrounding the barrens was subject several times to the invasion of sea water, and as we have seen the glaciated area, geologically much more ancient, must have been fairly scraped clear of vegetation by the ice. In other words, the New Jersey pine-barrens exist exclusively on the Beacon Hill formation, an area isolated by geological processes and maintaining a relict flora, which is much older in permanency of occupation than any of the rest of the flora near New York.

Ancestrally our local flora must have consisted of purely American

[2] *Torreya*, 12, 229–242, 1912.

plants, many of which were of southern affinities. Many southern species still reach their extreme northern outposts of distribution in this region. Most of the southern species are found on the coastal plain, but a few have spread north and west of it. At the present time over 13 per cent. of our local plants reach their northern limits within one hundred miles of the City of New York. Many other southern plants, also, range only slightly to the north of us.

About 8 per cent. of the native vegetation, also, consists of northern species that reach their southern limits within the local flora area, and many more are found to the south of us in the mountains. The great range of hills, stretching northeast-southwest from the Berkshires through the Catskills and the Highlands of the Hudson in New York, the Kittatinny in New Jersey and to the Blue Mountains of eastern Pennsylvania, serve literally as a broad highway down which a host of northern species are scattered, and to the seaward of which certain kinds have never been known to go. That other great group of species that creeps, almost insidiously, from the south, seems perforce to have been huddled between the mountains and the sea. The transition between these northern and southern elements of our flora is, of course, nothing like so sharp as the geological regions they generally occupy would seem to indicate. Many sporadic marauders have spread from both camps, apparently far out of their element. Sometimes these lonely outposts survive the competition of the new environment; that is notably the case of the hemlock in southern New Jersey, far from its usual rocky hillsides, and of the coast white-cedar (*Chamæcyparis*) which flourishes in the coastal-plain bogs, and maintains a rather splendid isolation at Greenwood Lake, in northern New Jersey. Scores of these cases could be cited illustrating the main lines of the distribution of our flora by occasional aggressive exceptions to it. Such sporadic occurrences form one of the most fascinating chapters in the history of our native flora, for are they not militant outposts of a mighty horde of conservatives? Sometimes they perish miserably as the little twin-flower has long since done on southern Long Island, miles from its mountain home. Of the number of such tragedies no man can even guess, still less speculate as to their causes, but speculation could weave about such occurrences, and they are very numerous even in such a limited area as this, a story the significance of which has breath-taking possibilities. For with these outcasts, whether living or dead, is bound up a whole history of changing climates and shifting levels of our continent—mighty forces which have scattered here and there mute little relics of their sport.

The real potency of these geological forces, or historical factors of distribution, is so great and its appeal to the imagination can be made so alluring, that we are in danger of attributing the general complexion of our vegetation almost solely to them. Nothing could give us such a

one-sided, wholly erroneous conception. Our present climate, particularly temperature, seems quite certainly to be the controlling factor in the present distribution of many of our native species. As to rainfall and the winds, their variation seems almost negligible in so small a region, but temperature is a much more serious matter. There seems to be a rather well-defined temperature barrier through which some plants have never been known to go.

For a variety of reasons that need not detain us here, the particular criterion of temperature response that has been studied in connection with our native flora is that of the length of the growing season. This is determined by figuring the number of frostless days in different parts of the area. The accompanying map illustrates the method better than a page of explanation could do. The arbitrarily drawn black line through the map indicates the dividing line between colder and warmer regions of our area. It marks, with occasional exceptions, the southerly limit in our area of many cold-country plants. North of it occur most of our higher elevations where the mountain species are found. The difference of three months in the growing season as between the Catskills and Cape May is very nearly as impressive as the conspicuously different vegetation of these widely separated localities.

The mental convenience of considering separately the effects of

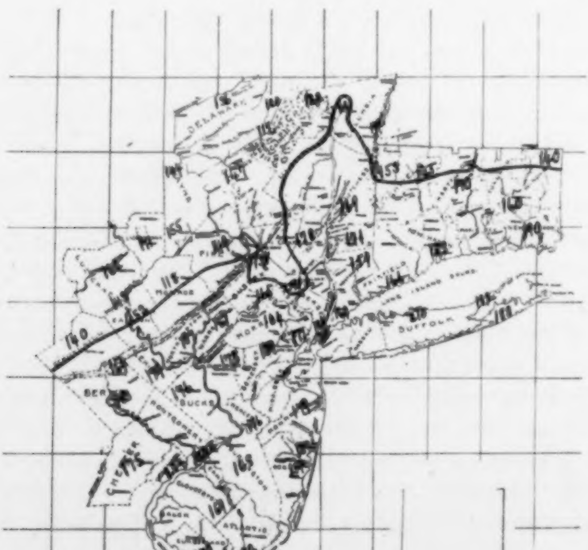

Fig. 1. Map Illustrating the Length of the Growing Season within 100 Miles of New York. The figures represent the number of days between the last killing frost in spring and the first of autumn. The dark line separates the warmer from the colder parts of the area, and indicates generally speaking a climatic barrier through which certain of our native plants have never been known to go.

geology and climate on the distribution of our flora must not blind us to the fact that these agencies do not work independently. The interaction of these, the further complication of the personal "aggressiveness" of certain species, if that term can be applied to plants, and many other minor factors, make the problem most complex. In any particular case it may be practically impossible to say whether a given plant exhibits response to climatic or geological factors, or to both, least of all as to what possible combination of both. All that can be done is to set down the facts of distribution, both with relation to geology and to climate, and to estimate the relative proportion of the potency of each. That such a study must spell a large measure of failure should deter no one. For by it is acquired an outlook upon the vegetation of an area that no preparation of lists of species can possibly confer. Upon such a conception a flora ceases to be a catalogue, mere scaffolding for the structure that is to follow, as necessary and as uninteresting as the telephone directory. Upon such a conception a flora need not concern itself with the latest hair-splitting refinements of the ever-present species-monger. All of these things are subsidiary to the larger problems that come from what may be called a causative study of a flora. By it each of our native plants takes on an added interest, to many there may be attached a history that fascinates the most unimaginative, to the whole is given a new impetus and a broader vision, which can make of any landscape something very like a dramatic spectacle.

Troublesome persons with a practical bent will want to know of what use such a study of any flora can be, least of all of the region near New York. Apart from its consideration as a great out-door experiment or laboratory where all sorts of principles of distribution can be studied at first hand, there are purely local problems that are commercially important. The draining and reclamation of our great salt-marsh areas on Long Island and in New Jersey, which is bound up with mosquito extermination, offers an attractive field of work where such knowledge will have a direct bearing. The profitable utilization of the southern part of Long Island, now a dreary waste of scrub-oak and pitch-pine, and of the pine-barrens of New Jersey, must involve the utilization of such studies to insure a full measure of success. The timber and crop possibilities of some parts of the area are well indicated by the wild vegetation, and the vegetational history of many parts of the region must serve as a clue to its most profitable future utilization. Thus a study of a flora from the standpoint of its fitness for its environment, and the intimately related study of the environment as fitted to the existing flora, must bulk large in any rational scheme for the agricultural or horticultural development of the region near the city, many parts of which are still wholly undeveloped, or, worse still, have been recklessly exploited.

TWO HISTORIC WORLD-PESTILENCES ROBBED OF THEIR TERRORS BY MODERN SANITATION

D. GREENBERG

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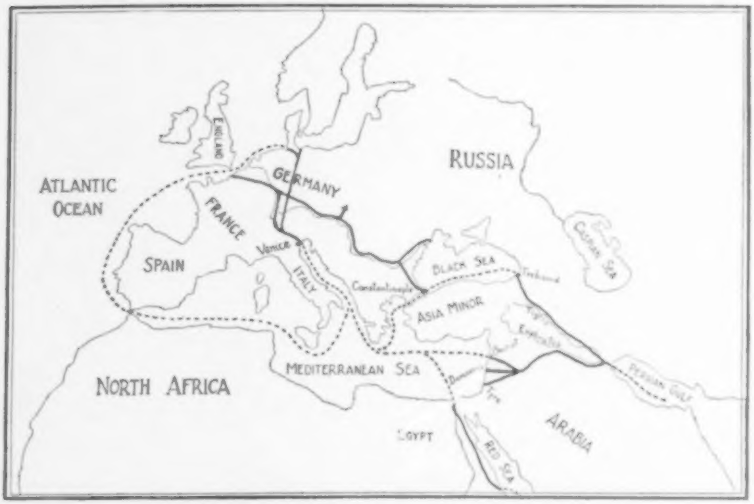
THE presence of bubonic plague at New Orleans two years ago and the recent outbreaks of cholera which have followed upon the progress of the war in Austria are striking reminders of two of the most terrible pestilences which have ever scourged the human race. They are of special interest to the student of history and geography because in the past these two diseases furnished admirable examples of the manner in which infection travels along trade routes in the wake of commerce and migration. The security which civilized countries may enjoy against their attacks is a brilliant demonstration of the triumphs of modern sanitary science.

Bubonic plague, the Black Death of the Middle Ages, with which our National Health Service has successfully grappled at New Orleans, is one of the most virulent diseases known to sanitarians and if not immediately recognized and attacked would claim victims without number. From time immemorial we have records of the presence of this pestilence. The Levant and adjoining countries have been the centers of plague for at least 3,000 years, due to their unique positions as the gateway between the East and the West. Biblical reference to this disease as occurring among the Philistines is found in the Book of Samuel (I Samuel, Chaps. V. and VI.). The world has passed through two worldwide epidemics of plague in the past and we are now in the midst of a third.

The first authentic epidemic of plague originated at Pelusium in Egypt, in 542 A.D. At that time Pelusium was a leading center for trade between the East and the West. By means of travelers and merchants the disease spread slowly through Alexandria and the rest of Egypt, on the one hand, and, on the other, passed into Palestine and over the then known world, following closely the highways of commerce. In order to trace more clearly the connection between commerce and the spread of the plague, it is well to remember that the main routes between Europe and the East were along the Mediterranean Sea and overland through Turkey, Germany and France. It was along precisely these routes that plague traveled, as can be seen from the accompanying maps. At the height of the epidemic the number of dead reached 5,000 a day and during some days the mortality rose to 10,000. According to Procopius, a witness of this epidemic,



TRADE ROUTES DURING THE MIDDLE AGES

FIG. 1.

it spared neither island nor cave nor mountain top where man dwelt. . . . Many houses were left empty and it came to pass that many from want of relatives and servants lay unburied for several days. At that time it was hard to find any one at business in Byzantium. Most people who met in the streets were bearing a corpse. All business had ceased, all craftsmen deserted their crafts. . . .

The second great epidemic of plague, known in history as the Black Death, originated in Mesopotamia, an old endemic center of this disease, about the middle of the eleventh century. It is thought that the returning Crusaders during the twelfth and thirteenth centuries assisted in this recrudescence of plague. Again the disease followed the routes of travel and commerce, but this time going further north into Europe. During this epidemic some 25,000,000 people, or one fourth of the population of Europe, are said to have perished. It was a veritable Black Death, for the degradation and misery which Europe suffered during the Middle Ages and from which it very slowly recovered, was largely due to this pestilential disease. Towns were left empty and all trade was at an end. All feared "the pestilence that walketh in darkness," none knowing when their turn would come to be smitten.

Venice at this time was the gateway through which the commerce of the East passed into Europe. Goods were brought by caravans to the shores of the Mediterranean or the Black Sea and from these points carried by ships to Italy to be distributed over Europe. On their way to the Mediterranean the caravans passed through the endemic centers of plague in Asia Minor, bringing the disease to all regions through which they passed.

The close parallelism between commercial routes and the spread of

FIG. 2. ORIGIN OF FIRST EPIDEMIC OF BUBONIC PLAGUE IN PELUSIUM, EGYPT, 542 A.D. (indicated by dot).

plague is illustrated by the fact that with the discovery of a new route to India by way of Cape of Good Hope the plague almost entirely disappeared from Europe. Just as a single rock may alter the course of a stream, so the discovery of this new route brought about the abandonment of the Mediterranean as a highway of commerce in favor of the water route by way of the Cape. As a result the seaports of northern Europe came into prominence as commercial centers whose connections with the East by way of the sea enabled them to avoid the old endemic centers of Asia Minor, and from this time on plague gradually disappeared from Europe.

The present epidemic, the third in the world's history, had its origin in the town of Junnan Fu in China in 1871. The disease spread to neighboring towns and reached Hongkong in 1894. From this point it traveled to India where it raged unchecked for more than ten years, carrying off 6,000,000 of the natives. Since its appearance in India in 1894, the plague has visited many of the larger seaports all over the world, the infection coming either from China or from India. In nearly every case the disease made its first appearance at a seaport, but in some cases, as at Johannesburg and Mecca, it was carried into the

FIG. 3. PROGRESS OF FIRST EPIDEMIC OF BUBONIC PLAGUE 544-570 A.D. (indicated by heavy shading).

interior by the hordes of gold seekers and pilgrims who flocked thither from infected areas.

Very few people realize that at the present time we are in the midst of a potentially serious pandemic and that only the constant vigilance of our authorities enables us to avert such epidemics as culminated in the Black Death of the fourteenth century. Beside the severe outbreaks in Manchuria and India, the present plague has manifested its presence in all of the principal Chinese seaports, traveling from its source of origin east to Melbourne, Brisbane and other Australian cities, south to Portugal and Scotland, and around the world to Brazil, Porto Rico and California. Yet in spite of this almost universal diffusion, our knowledge of the rat as the carrier of the germ of plague has made it possible to confine the disease within narrow limits everywhere outside of Asia.

From time immemorial various explanations have been given of the causes of plague. From Biblical records, we learn that this pestilence was considered a judgment which God in his wrath inflicts upon man to punish him for his sins. The connection between human plague and the disease among rodents was long ago suspected, for mention is made in the Book of Samuel of the fact that in order to stay the progress

FIG. 4. MAXIMUM EXTENSION OF FIRST EPIDEMIC OF BUBONIC PLAGUE 570–650 A.D. The disease spread to all the then known parts of the world (indicated by heavy shading).

of the disease offerings were made of golden images of mice and of the tumors characteristic of plague. Others have looked upon the disease as an emanation from contaminated soil, while others have blamed the air as the carrier of this pestilence.

Plague as we know it to-day is primarily a disease of the rat and only secondarily a disease of man. The germs of the disease are transmitted from rat to rat and from rat to man through the agency of the flea. When a rat dies of plague the fleas leave the dead animal and by preference attach themselves to other rats, attacking human beings only if there are no other rats to be found. The fleas which carry the germ of bubonic plague fasten themselves upon rats, from the blood of which they take their nourishment. Thus Jonathan Swift's jest about the endless chain of parasites which prey one upon the other, finds here an apt illustration of its scientific truth.

Modern sanitary science recognizes two steps in the solution of the plague problem—first the keeping out of plague cases by strict quarantine measures and second the elimination of the carrier, namely, the rat.

The latter solution is not as easy as one might at first suppose, for even on the best guarded ships and trains rats somehow find their way

FIG. 5. ORIGIN OF SECOND EPIDEMIC OF BUBONIC PLAGUE IN MESOPOTAMIA IN 1050 (indicated by dot).

aboard and take passage as stowaways. Having reached a new port they commence breeding very rapidly and before long have established a firm footing in their new environment. If we could successfully control the peregrinations of the rat the spread of plague would be easily checked, but this being impossible we must wage a war of extermination against him. This may be done either by killing the rats or by destroying their breeding places. The common methods of exterminating these rodents are by trapping, by poisoning, and by utilizing the rats' natural enemies. Traps and poisons have been used with some measure of success, but the rat by his constant association with man has become extremely wary. Rats have been known to enter traps, stand upon the pan with their hind legs, eat the bait and then carefully turn around and back out. They will eat the bread on which poison is spread so carefully that practically all the bread will be eaten while the poison will be left behind. The rats' natural enemies—the cat, dog, weasel and skunk—when given a fair chance will quickly drive him out. The war on rats carried on at San Francisco in 1907, at the time of the appearance of plague in that city, proved the great value of cats and dogs, and to-day San Francisco has a law requiring all structures of

FIG. 6. PROGRESS OF SECOND EPIDEMIC OF BUBONIC PLAGUE 1100-1200. This time the disease spread to the East as trade routes became extended.

800 square feet or less, within certain districts, to be raised high enough above the ground to allow these animals free access to the under side of the building.

Such methods will remove a considerable proportion of the rats, but it is only by prevention of their further breeding that we may hope satisfactorily to control their numbers. The rat requires two conditions for life—plentiful food and a place for nesting. Eliminate either of these and the problem of extermination is solved. To prevent the rat from getting sustenance all places where food-stuffs are stored, such as packing houses, bakeries, groceries, warehouses, grain sheds, docks and wharves, should be either rat proofed or should contain rat-proof receptacles for the food. Particular attention should also be paid to the proper disposition of garbage. To prevent the rat from entering buildings and nesting among the beams underneath the floor, the latter as well as the foundation walls should be concreted; and all openings in the basement screened.

The rats which are most dangerous are of course those brought from plague-ridden countries. To prevent such rats from landing recourse is had to the fumigation of ships and to the placing of rat guards—

FIG. 7. MAXIMUM EXTENSION OF SECOND EPIDEMIC OF BUBONIC PLAGUE, 1200–1450. The close parallelism between trade routes and the spread of the disease is indicated by comparing with Fig. 1.

which are nothing more than circular sheets of metal about two feet in diameter fastened in a vertical position on the ship's mooring lines. By preventing the plague rat from taking passage and from landing we can control the diffusion of plague to other ports; for we know that where trade will go there rats will go and where rats will go there plague will go. Our slogan should therefore be "No rats, no plague."

The other solution of the plague problem which consists in the quarantining of all cases of this disease, derives its name from the practise of the Venetians during the Middle Ages requiring the detention for forty days of all persons well or sick coming from an infected port. To-day, however, with our increased knowledge of sanitary science, preventive measures have become more efficient and less irksome. Ships coming from infected ports are detained for but a day, during which time the infected passengers are isolated, and the vessel fumigated. Isolation of individuals takes the place of quarantine against nations.

The plague very recently discovered at New Orleans would have brought consternation a decade ago, but to-day with the efficient protection of our ports no fear is entertained. Our knowledge of the rat as the carrier of the germ of plague has made it possible to keep this

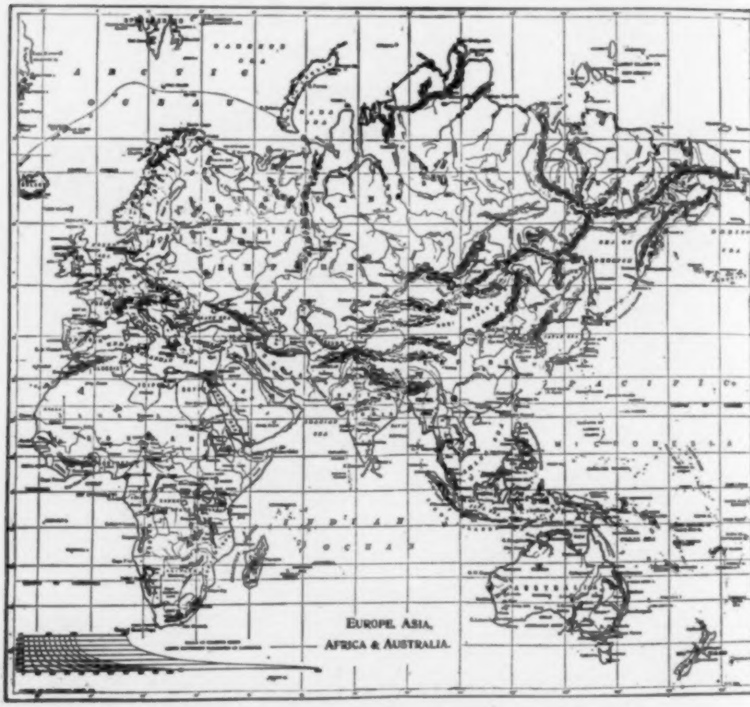


FIG. 8. ORIGIN OF THIRD EPIDEMIC OF BUBONIC PLAGUE IN JUNNAN FU, CHINA, 1871 (indicated by dot).

disease from spreading, to any considerable extent, anywhere outside of Asia. By enforcing quarantine laws, by disinfecting all ships suspected of harboring infected rats, by preventing the rat from landing, and by the comparative freedom of civilized cities from vermin, we have been able to keep plague from extending beyond the ports at which it has sporadically appeared. It is due to a thorough knowledge of these facts and to the careful sanitary precautions based on this knowledge, that we are not at present suffering from a Black Death similar to the one that ravaged and devastated Europe and Asia in the fourteenth century.

Another of the most dreadful diseases of medieval times is Asiatic cholera. Although this disease was described as early as the fourth century, yet no record appears of its occurrence in epidemic form until the sixteenth century. During the sixteenth, seventeenth and eighteenth centuries cholera was epidemic at various times in India. The disease is indigenous to that country and has been disseminated from India to all quarters of the globe. It is one of the most serious of scourges of unhappy India, the average annual mortality from cholera for the years 1898 to 1907 in India being 366,378.

FIG. 9. PROGRESS OF THIRD EPIDEMIC OF BUBONIC PLAGUE, 1874–1894.

With the increase of commercial intercourse between nations in the nineteenth century, cholera began to spread rapidly and usually, as in the case of plague, along the routes of trade and travel. It was not until 1817 that European physicians were attracted to the study of the disease by an outbreak of a violent epidemic at Jessore in Bengal. This epidemic extended westward from India along two routes—(1) by sea to the shores of the Red Sea, Egypt and the Mediterranean; (2) by land to northern India and Afghanistan, thence to Persia and Central Asia and so to Russia. The disease ravaged the northern and central parts of Europe, spread to England and subsequently appeared in France, Spain and Italy. Then crossing the Atlantic it made its appearance in North and Central America.

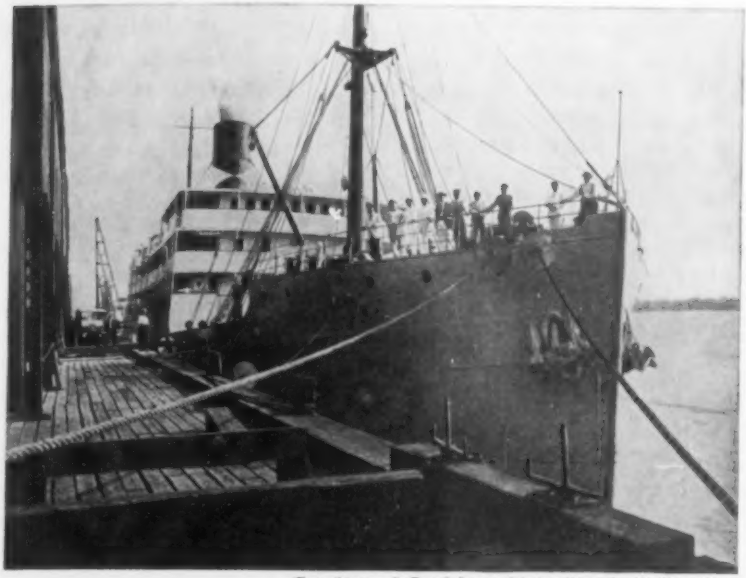
Four serious epidemics or pandemics of cholera have occurred, one from 1817–1823, another from 1826–1837, a third from 1846–1862, and a fourth from 1864–1875. In 1832 the disease appeared in New York and extended as far west as the military posts of the upper Mississippi. Later in 1848 it entered the United States through New Orleans, passed up the Mississippi and was carried across the continent by the searchers for gold on the way to California. Immigrant ships brought cholera to our shores again in 1857 and in 1892 and in the latter year only

FIG. 10. MAXIMUM EXTENSION OF THIRD EPIDEMIC OF BUBONIC PLAGUE, 1894. This time the spread of the disease is limited to Asia and occasionally to a seaport.

aggressive measures at New York prevented its spread to other points. The fear of cholera was the most successful lobbyist in favor of the creation of the New York city board of health during the epidemic of 1865–1866, and without whose aid the board would scarcely have succeeded in obtaining the needed powers and the required funds for efficient health measures.

While the home of cholera is in the tropics, there is scarcely a country in the world that has not been visited at one time or another by the ravages of this scourge. To-day, however, the disease is largely limited to tropical countries where insanitary conditions still exist.

Like bubonic plague, cholera is spread by man from place to place and this follows the lines of trade and travel. Pilgrimages and fairs are a great factor in the dissemination of the disease, favored by the overcrowding and insanitary conditions usually existing at such gatherings. The dispersal of such gatherings then disseminates the disease over wide areas. One of the most important of these recurrent festivals is held at Jaganath temple at Puri in the province of Bengal. Upwards of 100,000 pilgrims gather at this place during July when the principal festival is held. Endemic cholera is rarely absent in Puri and out-



Courtesy of Louisiana State Board of Health.

FIG. 11. SAFEGUARDING A PIER AGAINST RATS. By means of the rat guards on the hawsers and by fenders, rats are prevented from landing.

breaks almost invariably occur at the time of these gatherings—in 1899, 1,216 cases with 1,020 deaths occurred at the July festival in Puri alone.

Cholera, however, spreads along avenues not common to plague. One of the most important of the vehicles of this disease is water. Numberless epidemics have been traced to the pollution of a water supply by a cholera patient. A notable classic example is the Hamburg epidemic of 1892. Cholera was brought to Hamburg by immigrants either from Russia or France. The waters of the Elbe River receiving the wastes of the city were infected with the discharges of the cholera patients, and this water was used by the inhabitants without previous purification. The water supply of Altona adjoining Hamburg was taken from the same river, but first subjected to sand filtration. An outbreak of cholera ensued in Hamburg with 16,957 cases and 8,606 deaths, while 516 cases and 316 deaths occurred in Altona, most of the cases occurring in Altona being traced directly to infection in Hamburg.

Reports from European battlefields inform us of the presence of cholera in Austria. This scourge has been responsible for deaths without number in the wars of the past, for war, famine and pestilence go hand in hand. No army can be considered safe if once it should appear in the theater of operations unless the most stringent precautions against its extension are taken.

In the Crimean war during the months of July and August of 1853, cholera lost to the French army before a shot had been fired as many men as were killed by the enemy during the entire campaign and siege. The number of cases totalled 12,258 and deaths 6,013. The British in this war lost 11,097 men from disease and of this number one fourth died of cholera.

During the war between Austria and Prussia in 1866, the latter country lost more men from cholera than from the casualties of battle.

In our own Civil War upwards of 3,400 cases and 1,500 deaths resulted from the ravages of cholera. This scourge almost destroyed an entire body of recruits brought from New York.

During the war between China and Japan in 1894–1895, cholera claimed 9,658 cases with 5,991 deaths, out of a total of 15,860 deaths from disease, from a mean strength of 227,600.

To-day we know that disease germs are stronger and more deadly than bullets, so that the soldier is sent forth prepared to meet cholera or other scourges that attack men in the field. The soldier is protected against typhoid and cholera by vaccination against these diseases, by attention to the sanitary conditions of the camp, by sterilizing the water supply, by protecting food from flies, by caring for the wastes and by isolation of cases of such communicable diseases. That such precautions can be maintained under the stress of a great war has already been demonstrated.

It is certain, however, that in times of peace cholera, like plague, has no longer any terrors for modern civilization. In the summer of 1911, ship after ship came into the harbor of New York from cholera-infected ports. They were detained for no long period of quarantine; but in 24 to 48 hours every passenger was subject to examination and the carriers of the deadly "comma bacillus" were picked out and isolated. The examination of 26,930 persons at the port of New York revealed 27 such carriers. The rest of the passengers were sent on their way, and the pestilence which used to pass in great waves from continent to continent found an impassable barrier placed in its path by the culture tube and the microscope of the bacteriologist.

THE PROGRESS OF SCIENCE

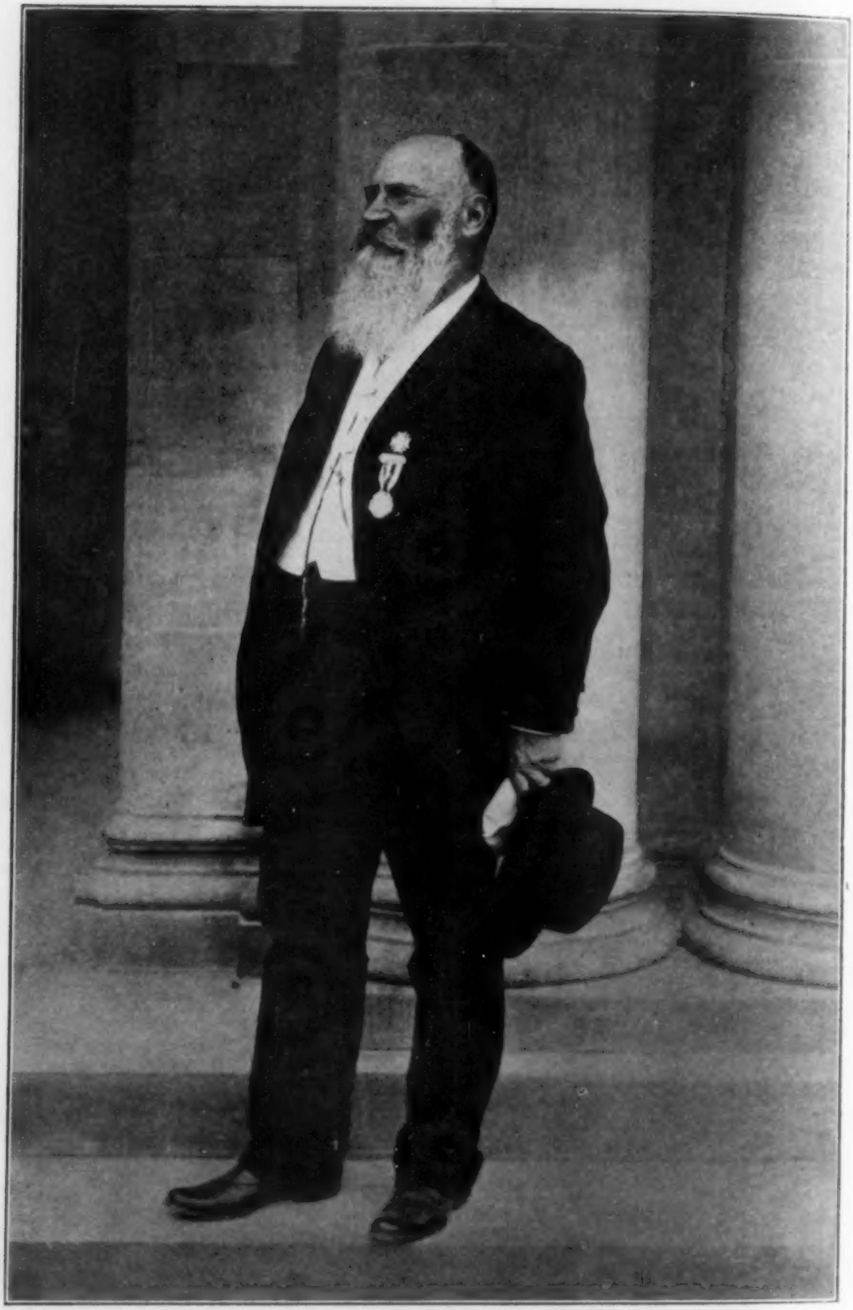
WORK OF THE NATIONAL RESEARCH COUNCIL

At the recent meeting of the National Academy of Sciences in Washington, one of the sessions was devoted to the work of the National Research Council. Dr. George E. Hale, of the Mt. Wilson Solar Observatory, chairman of the council, presided, and reports were made by the following chairmen: Dr. Charles D. Walcott, secretary of the Smithsonian, for the military committee; Dr. Robert A. Millikan, of the University of Chicago, for the physics committee; Dr. Marston T. Bogert, of Columbia, for the chemistry committee; and Dr. Victor C. Vaughan, director of the Medical Research Laboratory, University of Michigan, for the medicine and hygiene committee.

In connection with the work accomplished by the military committee, Dr. Walcott, who is also a member of the National Advisory Committee for Aeronautics, stated that investigations had been conducted with noxious gases as employed for military purposes; problems connected with all forms of signalling had been studied; the utilization of opium for obtaining a supply of morphine for medical purposes had been considered, and improvements had been suggested in the service army blanket, which is not thought to be warm enough. Other work for military establishments of the government is confidential.

In reporting for the committee on physics, Dr. R. A. Millikan stated that they were cooperating with the American Physical Society and the American Association for the Advancement of Science in an effort to find the men and the means for attacking certain physical problems which are now confronting the national government. While no information as to the exact nature of these researches was given out, the chairman stated that four or five of them were submarine problems, several pertained to aeronautics, and some were optical, having to do with range-finding devices and the production and use of optical glass. Experiments with the X-ray are being conducted for the government, as are studies in thermal conductivity, atmospheric electricity, as encountered by airships, and even the manufacture of guns. The study of these problems has brought to life the vital need of a central coordinating body, such as the council. For example, certain questions concerning the submarine were being considered separately by a naval investigating board, three of the industrial research laboratories, and a number of universities before the solution of its various phases are undertaken and distributed by the council. Encouraging results have been secured as the committee has become familiar with the general lines of attack of each investigation.

At the request of the Council of National Defense, the National Research Council has entered into close relations with it, acting as one of its departments. It is, in this capacity, charged with the organization of scientific research so as most effectively to contribute to national defense directly, and to the support and development of those industries affected by the war. In order to carry out this scheme of cooperation the Research Council and several of its subcommittees have secured offices in the Munsey Building, Washington, D. C., where also are the headquarters of the Defense Council. The Research Council as a whole is represented by its chairman, Dr. George E. Hale, and by Dr. R. A. Millikan, the vice-chairman, charged with the correlation of research problems in general. The subcommittees are represented in Washington as follows: Military: Dr. C. D. Walcott, chairman; Dr. S. W. Stratton, secretary, and other



WILHELM VON WALDEYER

The distinguished anatomist of the University of Berlin who has been made a hereditary noble on the occasion of his eightieth birthday. The photograph was taken at the St. Louis Exposition.

members representing various departments of the government; Physics: Dr. R. A. Millikan, Dr. C. E. Mendenhall; Chemistry: Dr. Marston T. Bogert, Dr. A. A. Noyes; Medicine and Hygiene: Dr. Victor C. Vaughan; Engineering: Dr. W. F. Durand.

As rapidly as possible these representatives are getting into touch with defense research problems through the military branches of the government, in which matter the military committee plays an important part, at the same time bringing these problems to the attention of the research men and organizations. The representatives in Washington will, among other things, act as a central clearing house for the reception of problems from the government, and their proper distribution; will sift, distribute and follow up suggestions of a scientific or engineering nature received from any source, individuals or groups; and will keep those who are working on specific problems informed as to the progress being made by others working along the same lines. It is the desire of the Research Council to do anything possible to stimulate scientific activity and aid in any possible way its direction and concentration upon the most vital and immediate problems.

INLAND FISH AND GAME AS FOOD SUPPLY

According to a statement issued by The New York State College of Forestry at Syracuse University, the fish and game which can be produced from lakes and non-agricultural areas within New York State will go a long way toward augmenting the meat supply. Acting Dean F. F. Moon has appeared before the Governor's Patriotic Agricultural Commission and made a number of specific suggestions concerning the increase in the production and use of fish from inland lakes, and game which could be raised on lands unsuited to tillage throughout New York State. Dr. Charles C. Adams, at the zoology department at the College of Forestry is authority for the statement that 100 tons of eels are caught each year in Oneida Lake, and that press notices last fall tell of the capture by game wardens of several trap nets illegally set in this lake from which about thirty tons of fish were set free. Acting Dean Moon suggests: That seining of inland lakes and streams by state officials for mature food fish be permitted during the period of the war. The taking of these fish should not be allowed during the breeding season, and the possession of seines by any person, except state officials, should be made illegal. All suitable food fish in inland waters should be used under this plan without exterminating any species.

Federal and state hatcheries in New York are already turning out large numbers of fry, but when liberated a great many of these are destroyed by natural enemies. Fish nurseries can be built cheaply and quickly, and will turn out great quantities of fish which would soon reach market size. Federal or state employees, who are often released from hatcheries during the summer, could be utilized to take charge of one or a group of these nurseries.

Carp breeds prolifically, matures rapidly and is capable of furnishing a tremendous amount of protein food. At present this fish is found on the markets of thirty-five states, and about 20,000,000 pounds are sold annually. The disfavor with which many consider carp should not belittle its value as food under war conditions.

As a result of conservative game regulations in Germany, venison can ordinarily be bought during any season, and is now more plentiful than beef, butter or eggs. There is no reason, in spite of possible opposition from certain types of sportsmen, why a substantial reserve meat supply should not be created by this provision. Game farms now owned by the state might be turned primarily into food-producing establishments. The equipment used for turning out pheasants and other fowls could be used for

JOSEPH HENRY

Model of a statue by John Flanagan now in State Museum at Albany, N. Y. When cast in bronze it is to be erected in the park facing the Albany Academy, where Henry conducted his experiments on electromagnetism.

hatching and rearing ducks or other poultry which would mature rapidly. Belgian hares could also be raised and all the animals produced would be available for use at state institutions or for distribution at cost for breeding purposes in order to stimulate private food production.

The possible utilization is suggested of cutover state forest lands for grazing purposes under strict supervision, sheep, for instance, could be fattened on this wild land, either publicly or privately owned. The Federal Forest Service received during the year 1916, $1,210,000 from grazing fees, and two years ago the chief forester reported that one sixth of the total meat supply of the nation came from animals grazed, for a portion of the year at least, within the boundaries of the national forests. All these suggestions, according to Acting Dean Moon, are in accordance with the belief that the college has maintained during its organization that the freest use should be made of all waters and non-agricultural land for the production of the necessities of life.

WELFARE WORK IN BRITISH MUNITION FACTORIES

The efforts being made in Great Britain to conserve the health of munition workers through systematic and carefully planned welfare supervision in factories and workshops are described in a bulletin issued by the Bureau of Labor Statistics of the U. S. Department of Labor. This bulletin, the second one in the group reproducing documents giving foreign experience in dealing with labor conditions growing out of the war, includes reprints of the memoranda published by the British Health of Munition Workers Committee covering the subjects of welfare supervision, industrial canteens, canteen construction and equipment, investigations as to workers' food and suggestions as to dietary, and washing facilities and baths. The bulletin also includes an article on "The value of welfare supervision to the employer," by B. Seebohm Rowntree, a manufacturer, and director of the welfare department, British Ministry of Munitions.

The home secretary has been given powers to secure the welfare of munition workers by issuing orders, regulating such matters as arrangements for preparing or heating and taking meals, supply of drinking water and protective clothing, ambulance and first-aid provision, supply and use of seats in workrooms, facilities for washing, accommodation for clothing, and supervision of workers. No contribution may be exacted from workers for these benefits, but for additional benefits which the employers may not reasonably be expected to provide, an assessment may be made if two thirds of the workers assent, in which event the workers are permitted to have representation in the management of the arrangements, accommodation or other facilities to be provided.

It appears from the welfare memoranda that industrial efficiency depends largely upon consideration of the health of munition workers through proper attention to such questions as housing, transit, canteen provision and individual welfare of the employee, which have become of vital concern to manufacturers who appreciate the necessity of conserving their labor force in order to attain a maximum of production in the shortest space of time. Managers generally testify to the value of the services rendered by welfare supervisors. The committee recommends as particularly important the appointment of a competent woman welfare supervisor of experience and sympathy who shall devote her attention exclusively to problems affecting the health of women and girls, to the character and behavior of fellow women workers, to the maintenance of suitable and sufficient sanitary accommodations, to the capacity of workers to withstand the physical strain and stress of work, and to their power to endure long hours, overtime and nightwork.

Closely allied to welfare supervision as noted is the necessity for adequate provision of canteen facilities where workers may obtain a dietary containing a sufficient proportion and quantity of nutritive material, sufficiently varied, easily digestible, and at a reasonable cost, which will enable them to maintain their health and output. It is the conviction of the committee that "in the highest interest of both employers and workers proper facilities for adequate feeding arrangements should be available in or near, and should form an integral part of, the equipment of all modern factories and workshops." This policy "has abundantly justified itself from a business and commercial point of view." Marked improvement in the physical condition of workers, a reduction of sickness, less absence and broken time, less tendency to alcoholism, and increased efficiency and output, a saving of time to the workmen, greater contentment, and better midday ventilation of the workshops are some of the benefits noted.

The bulletin includes some suggestions as to dietary for munition workers, based upon a careful analysis of meals provided by canteens and hotels and the food brought by workers.

The committee urges the importance of providing opportunities for washing so that workers may be clean and tidy when they leave their employment. Bathing facilities should be provided in many industries especially where workers are exposed to great heat and excessive dust or brought into contact with poisonous materials.

The article on the value of welfare work to the employer is based upon the proposition that since the employer gives careful attention to his machinery in order to maintain output, he should give at least as much consideration to human beings, which are infinitely more complex and delicate than machines, if he would obtain a satisfactory output.

SCIENTIFIC ITEMS

We record with regret the death of Arnold Hague, a distinguished geologist of the U. S. Geological Survey, and of Herbert William Conn, professor of biology in Wesleyan University and Connecticut state bacteriologist.

At the recent meeting of the National Academy of Sciences, Dr. Charles D. Walcott, secretary of the Smithsonian Institution, was elected president, in succession to Professor William H. Welch, of the Johns Hopkins University. Professor A. A. Michelson, of the University of Chicago, was elected vice-president. The following members were elected: Edward Kasner, mathematics; Walter S. Adams, astronomy; Theodore Lyman, Walter C. Sabine, S. W. Stratton, physics; W. R. Whitney, chemistry; J. J. Carty, electrical engineering; W. F. Durand, marine engineering; H. M. Howe, metallurgy; E. O. Ulrich, geology; Robert Ridgway, ornithology; Harvey Cushing, William S. Halsted, surgery; L. H. Bailey, botany; Edward L. Thorndike, psychology.

The Council of National Defense and the National Research Council have sent six American men of science to England and France to study problems arising out of the war. Members of the party and the subjects in which they will specialize are: Dr. Joseph S. Ames, Johns Hopkins University, aeronautical conditions; Dr. Richard P. Strong, Harvard University, and Dr. Linsley R. Williams, assistant health commissioner of New York State, health and sanitation; George A. Hulett, Princeton University, chemistry of explosives; Dr. Harry Fielding Reid, Johns Hopkins University, scientific map making and photography from airplanes, and Dr. George R. Burgess, of the Federal Bureau of Standards, metals suitable for guns and rigid dirigibles.

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